SB4251E00
May. 2007

Service Manual

G424FE LP/Dual Fuel Engine
G424F LP Engine

G20P-5, G25P-5, G30P-5, G33P-5, G35C-5
GC20P-5, GC25P-5, GC30P-5, GC33P-5

Important Safety Information

Most accidents involving product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Read and understand all safety precautions and warnings before operating or performing lubrication, maintenance and repair on this product.

Basic safety precautions are listed in the “Safety” section of the Service or Technical Manual. Additional safety precautions are listed in the “Safety” section of the owner/operation/maintenance publication.
Specific safety warnings for all these publications are provided in the description of operations where hazards exist. WARNING labels have also been put on the product to provide instructions and to identify specific hazards. If these hazard warnings are not heeded, bodily injury or death could occur to you or other persons. Warnings in this publication and on the product labels are identified by the following symbol.

⚠ WARNING

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.
Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Operations that may cause product damage are identified by NOTICE labels on the product and in this publication.

DOOSAN cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are therefore not all inclusive. If a tool, procedure, work method or operating technique not specifically recommended by DOOSAN is used, you must satisfy yourself that it is safe for you and others. You should also ensure that the product will not be damaged or made unsafe by the operation, lubrication, maintenance or repair procedures you choose.

The information, specifications, and illustrations in this publication are on the basis of information available at the time it was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service given to the product. Obtain the complete and most current information before starting any job. DOOSAN dealers have the most current information available.

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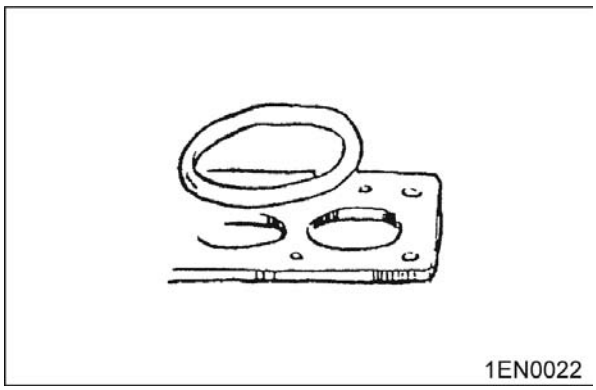
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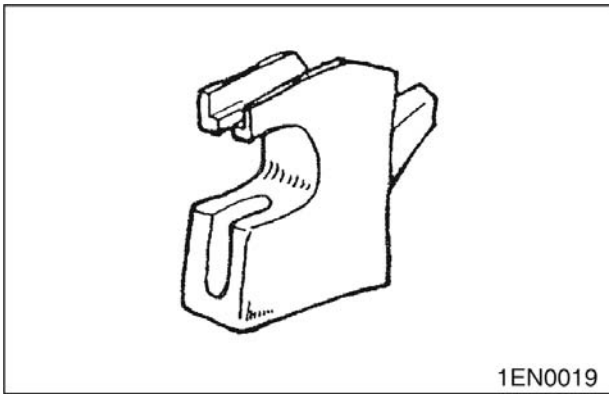
Precautions before Service

Removal and Disassembly



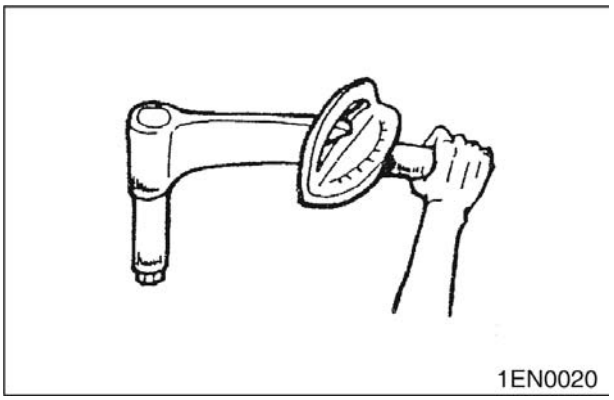
For prevention of wrong installation or reassembly and for ease of operation, put mating marks to the parts where no function is adversely affected.

Special Tool



Be sure to use Special Tools when their use is specified for the operation.
Use of substitute tools will result in malfunction of the part or damage it.

Tightening Torque



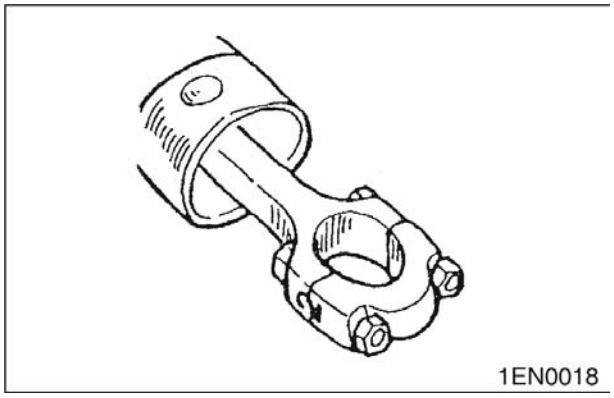
Tighten the part properly to specified torque.

Sealant



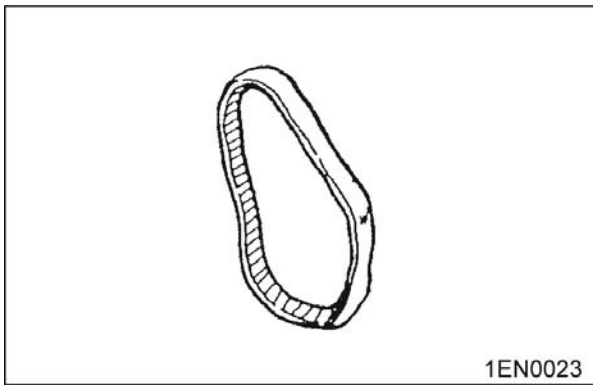
Use specified brand of sealant.
Use of sealant other than specified sealant may cause water or oil leaks.

Replacement Part



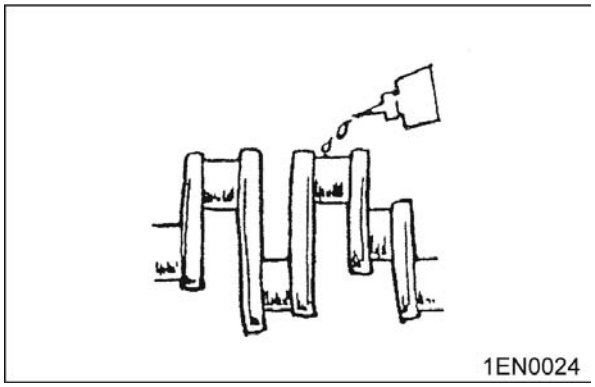
When oil seal, O-ring, packing and gasket have been removed, be sure to replace them with new parts.
However, rocker cover gasket may be reused if it is not damaged.

Rubber Parts



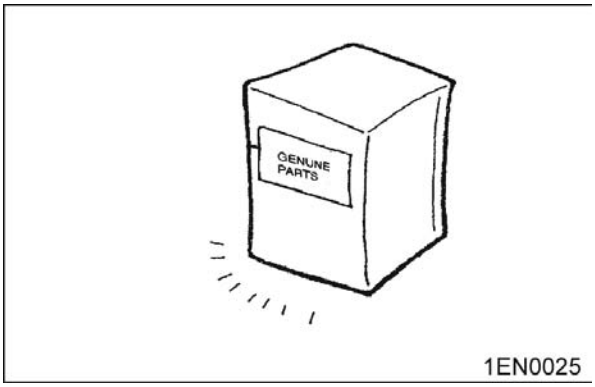
Do not stain timing belt and V-belt with oil or water. Therefore, do not clean the pulley and sprocket with detergent.

Oil and Grease



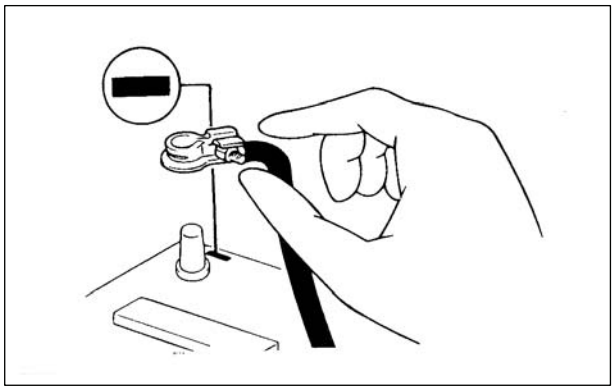
Before reassembly, apply specified oil to the rotating and sliding parts.

Genuine Part



When the part is to be replaced, be sure to use genuine part.
For selection of appropriate parts, refer to the Parts Catalog.

Electrical System



1. Be sure to disconnect the battery cable from the negative (-) terminal of the battery.

2. Never pull on the wires when disconnecting connectors.

3. Locking connectors will click when the connector is secure.

4. Handle sensors and relays carefully. Be careful not to drop them or hit them against other parts.

Precautions for catalytic Converter

⚠ CAUTION

If a large amount of unburned gasoline flows into the converter, it may overheat and create a fire hazard. To prevent this, observe the following precautions and explain them to your customer.

1. Use only unleaded gasoline.

2. Do net run the engine while the truck is at rest for a long time. Avoid running the engine at fast idle for more than 5 minutes and at idle speed for more than 10 minutes.

3. Avoid spark-jump tests. Do spark-jumps only when absolutely necessary. Perform this test as rapidly as possible and, while testing, never race the engine.

4. Do not measure engine compression for an extended time. Engine compression tests must be made as rapidly as possible

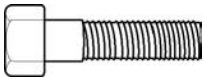
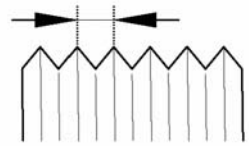
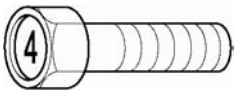
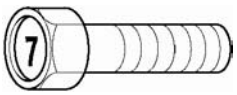
5. Do not run the engine when the fuel tank is nearly empty. This may cause the engine to misfire and create and extra load on the converter.

6. Avoid coasting with the ignition turned off and during prolonged braking

7. Do not dispose of a used catalytic converter together with parts contaminated with gasoline or oil.

Tightening Torque

Tightening Torque Table of Standard Parts

Bolt nominal diameter (mm)	Pitch (mm)	Torque (kg·m)	
		Head mark 4	Head mark 7
			
M5	0.8	0.3 ~ 0.4	0.5 ~ 0.6
M6	1.0	0.5 ~ 0.6	0.9 ~ 1.1
M8	1.25	1.2 ~ 1.5	2.0 ~ 2.5
M10	1.25	2.5 ~ 3.0	4.0 ~ 5.0
M12	1.25	3.5 ~ 4.5	6 ~ 8
M14	1.2	7.5 ~ 8.5	12 ~ 14
M16	1.5	11 ~ 13	18 ~ 21
M18	1.5	16 ~ 18	26 ~ 30
M20	1.5	22 ~ 25	36 ~ 42
M22	1.5	29 ~ 33	48 ~ 55
M24	1.5	37 ~ 42	61 ~ 70
M5	0.8	0.3 ~ 0.4	0.5 ~ 0.6
M6	1.0	0.5 ~ 0.6	0.9 ~ 1.1
M8	1.25	1.2 ~ 1.5	2.0 ~ 2.5
M10	1.25	2.5 ~ 3.0	4.0 ~ 5.0

NOTE: The torques shown in the table are standard vales under the following conditions.

1. Nuts and bolt are made of steel bar and galvanized.

2. Galvanized plain steel washers are inserted.

3. All nuts, bolts, plain washers are dry.

NOTE: The torques shown in the table are not applicable,

1. When spring washers, toothed washers and the like are inserted.

2. If plastic parts are fastened.

3. If oil is applied to threads and surfaces.

NOTE: If you reduce the torques in the table to the percentage indicated below under the following conditions, it will be the standard value.

1. If spring washers are used : 85%

2. If threads and bearing surfaces are stained with oil: 85%

Recommended Lubricants and Capacities

Recommended Lubricants

Lubricant	Specification	Remarks
Engine Oil	API Classification SJ or above	SAE 10W30 or SAE 5W30
Coolant (Antifreeze)	Automotive antifreeze suitable for gasoline engines having aluminum alloy parts	Concentration level 50%(normal) Concentration level 40%(tropical)

Lubricant Capacities

Description		G(C)20/25/30/33P-5
Engine Oil (liters)	Oil Pan	4.25
	Oil Filter	0.3
	Total	4.5
Coolant (liters)	Engine	3.0
	Radiator & Hoses	6.0
	Total	9.0

Engine Model and Engine Serial Number

Engine Model	Fuel Type	Emission Regulation
G424FE	LP/Dual Fuel	EPA/CARB* 2007 Compliant
G424F	LP	

* EPA: Environmental Protection Agency

* CARB: California Air Resources Board

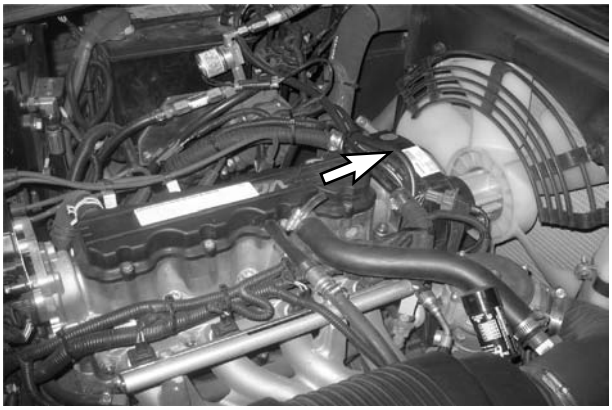
G424FE Engine

- Comply with EPA 2007 Emission Regulation
- Electronic Control by ECM
- Certified LP/Dual Fuel System available
  - Closed loop LP Carburetion system
  - Closed loop MPI Gasoline system
- 3-way Catalytic Muffler is standard

G424F Engine

- Not comply with EPA 2007 Emission Regulation
- Electronic Control by ECM
- Standard LP System available
  - Open loop LP Carburetion system
- Muffler is standard

Indication of Engine Model and Serial Number



Engine Model	Engine Serial Number
G424FE/G424F	30700001 to 39999999

Features and Benefits of G424FE/G424F Engine

- Al head with valve seat inserts
  - Aluminum head and valve seat system
- SOHC 8 valve system
- Timing belt system
- Distributorless Ignition system
- Electronic control system by ECM (Engine control module)
  - Drive-by-wire system
  - Higher efficiency and lower fuel consumption
  - Min./Max. governor control
  - Automatic engine protection from overheating and/or low engine oil pressure
  - Automatic transmission protection from overheating
  - Engine diagnostics by service-tool software
  - Forklift ground speed limit (optional)

General Specification

	G424FE Engine	G424F Engine
GENERAL DESCRIPTION		
ENGINE TYPE:	Water-cooled, Inline 4-Cycle, 4-Cylinders	
COMBUSTION SYSTEM:	Squish Combution Chamber	
INTAKE MANIFOLD	Cast Aluminum (with injector ports)	
EXHAUST MANIFOLD	Cast Iron (dual channel)	
VALVE CONFIGURATION:	SOHC, 2 Valves per Cylinder	
VALVE LIFTER/LASH ADJUSTER	Stationary Hydraulic Lash Adjusters	
VALVE ROTATOR	Exhaust Rotator	
CAMSHAFT DRIVE	Timing belt system (20 mm Toothed Belt)	
DISPLACEMENT:	2,405 cc (147 cid)	
BORE x STROKE	87 mm (3.44 in) x 100 mm (3.94 in)	
BLOCK STRUCTURE	Grey Cast Iron	
HEAD STRUCTURE	Aluminum with seat inserts	
COMPRESSION RATIO:	9.6:1	
COMPRESSION PRESSURE:	1,240 kPa (180psi) Minimum	
VALVE TIMING:	Intake Valve: 17°30' BTDC/ 76°30' ABDC Exhaust Valve: 58°30' BBDC/ 35°30' ATDC	
FIRING ORDER:	1-3-4-2	
WEIGHT:	120 kg	
ENGINE ROTATION:	Counter-Clockwise (CCW) when viewed from Flywheel End	
FUEL TYPE:	LPG, Dual Fuel (LPG or Gasoline)	
CRANK VENTILATION	Foul Air System with PCV	
IGNTION SYSTEM		
IGNITION TYPE:	Distributorless (waste spark)	
IGNITIOIN TIMING:	Electronic controlled by ECM	
IGNITION COIL:	12 V operation volt	
SPARK PLUGS:	0.035" (0.8-0.9 mm) Air Gap	
LUBRICATION SYSTEM		
OIL PRESSURE:	282 - 324 kPa @ 1400 rpm	
OIL TEMPERATURE:	Upper Limit: 125 °C (257°F) Recommended: 99 – 110 °C (210 - 230°F) Lower Limit:80 °C (176 °F)	
OIL PAN	Cast Aluminum	
OIL PAN CAPACITY	4.25 L (EXCLUDES OIL FILTER)	
OIL FILTER:	0.3 L	
ENGINE OIL SPECIFICATION:	API - SJ, SAE 10W30 or SAE 5W30	

	G424FE Engine	G424F Engine
COOLING SYSTEM		
WATER PUMP ROTATION:	Toothed Timing Belt Drive- Clockwise from front of engine	
THERMOSTAT:	Opening Temperature: 82°C (180°F) Fully Open Temperature: 95°C (203°F)	
COOLING WATER CAPACITY:	3.0 L	
LP FUEL SYSTEM		
LP FUEL SYSTEM	Closed loop LP Carburetion System	Open loop LP Carburetion System
MIXER:	Diaphragm Type Air Valve Assembly inside, Downdraft (Model: CA-100)	Diaphragm Type Air Valve Assembly inside, Downdraft (Model: CA-100)
REGULATOR:	Two-Stage Negative Pressure Regulator (Model: N-2007)	Two-Stage Negative Pressure Regulator (Model: N-2001)
FUEL TRIM VALVE (FTV):	Dual Dither System	None
FUEL FILTRATION:	40 Microns Maximum	40 Microns Maximum
GASOLINE FUEL SYSTEM		
GASOLINE FUEL SYSTEM	Closed loop MPI System and In-Tank Fuel Pump System	
FUEL PUMP MODULE	Electric Fuel Pump (12V)	
	Fuel Filter & Strainer	
	Gasoline Pressure Regulator (3.5 bar)	
FUEL INJECTOR ASS'Y	Electric Fuel Injector (12V)	
ENGINE ELECTRIC		
ENGINE CONTROL MODULE(ECM):	12 V operation volt, 48 pins of I/O	
CRANK SENSOR	VR (Variable Reluctance)	
CAM SENSOR	Hall sensor (Dual fuel engine only)	
TMAP:	Intake Air Temp. & Manifold Absolute Press. Sensor	
PEDAL ANGLE SENSOR:	Two-Output Signals (Installed on Accelerator Pedal)	
OXYGEN SENSOR:	Dual Oxygen Sensor System	None
ECT-ECM:	Engine Coolant Temperature Sensor for ECM	
ECT-GAUGE	Engine Coolant Temp. Sensor for GAUGE on Instrument Panel	
TPS:	Throttle Position Sensor (built in Throttle Body)	
THROTTLE BODY:	Electronic Throttle Body	
LP FUEL LOCK-OFF:	12 V operation volt	
ENGINE OIL PR. S/W:	14-41 kPa	
STARTING MOTOR:	12 Volts, 1.4 kW	
ALTERNATOR:	13.5 Volts, 80 A	
EXHAUST SYSTEM		
Muffler	Catalytic Muffler	Muffler (without catalyst)

G424F/G424FE Engine Power and Torque

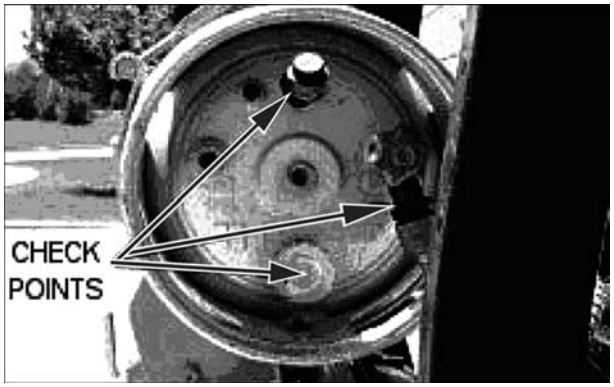
ENGINE MODEL	unit	G424FE		G424F
		G424FE-LP G424FE-DF(LP)	G424FE-DF(GAS)	G424F-LP
RATED POWER	kW	46.2	44.7	46.2
	hp	62	60	62
	PS	62.9	60.8	62.9
	rpm	2,550	2,550	2,550
MAX TORQUE	N-m	181	172	181
	ibf-ft	134	127	134
	Kgf-m	18.5	17.5	18.5
	rpm	2,200	2,200	2,200
GOVERNED SPEED	rpm	2,600	2,600	2,600
LOW IDLE	rpm	750	750	750

Chapter 2. RECOMMENDED MAINTENANCE

Suggested maintenance requirements for an engine equipped with an MI-07 fuel system are contained in this section. The operator should, however, develop a customized maintenance schedule using the requirements listed in this section and any other requirements listed by the engine manufacturer.

General Maintenance

Test Fuel System for Leaks



- Obtain a leak check squirt bottle or pump spray bottle.
- Fill the bottle with an approved leak check solution.
- Spray a generous amount of the solution on the fuel system fuel lines and connections, starting at the storage container.
- Wait approximately 15-60 seconds, then perform a visual inspection of the fuel system. Leaks will cause the solution to bubble.
- Listen for leaks
- Smell for LPG odor which may indicate a leak
- Repair any leaks before continuing.
- Crank the engine through several revolutions. This will energize the fuel lock-off and allow fuel to flow to the pressure regulator/converter. Apply additional leak check solution to the regulator/ converter fuel connections and housing. Repeat leak inspection as listed above.
- Repair any fuel leaks before continuing.

Inspect Engine for Fluid Leaks

- Start the engine and allow it to reach operating temperatures.
- Turn the engine off.
- Inspect the entire engine for oil and/or coolant leaks.
- Repair as necessary before continuing.

Inspect Vacuum Lines and Fittings

- Visually inspect vacuum lines and fittings for physical damage such as brittleness, cracks and kinks. Repair/replace as required.
- Solvent or oil damage may cause vacuum lines to become soft, resulting in a collapsed line while the engine is running.
- If abnormally soft lines are detected, replace as necessary.

Inspect Electrical System

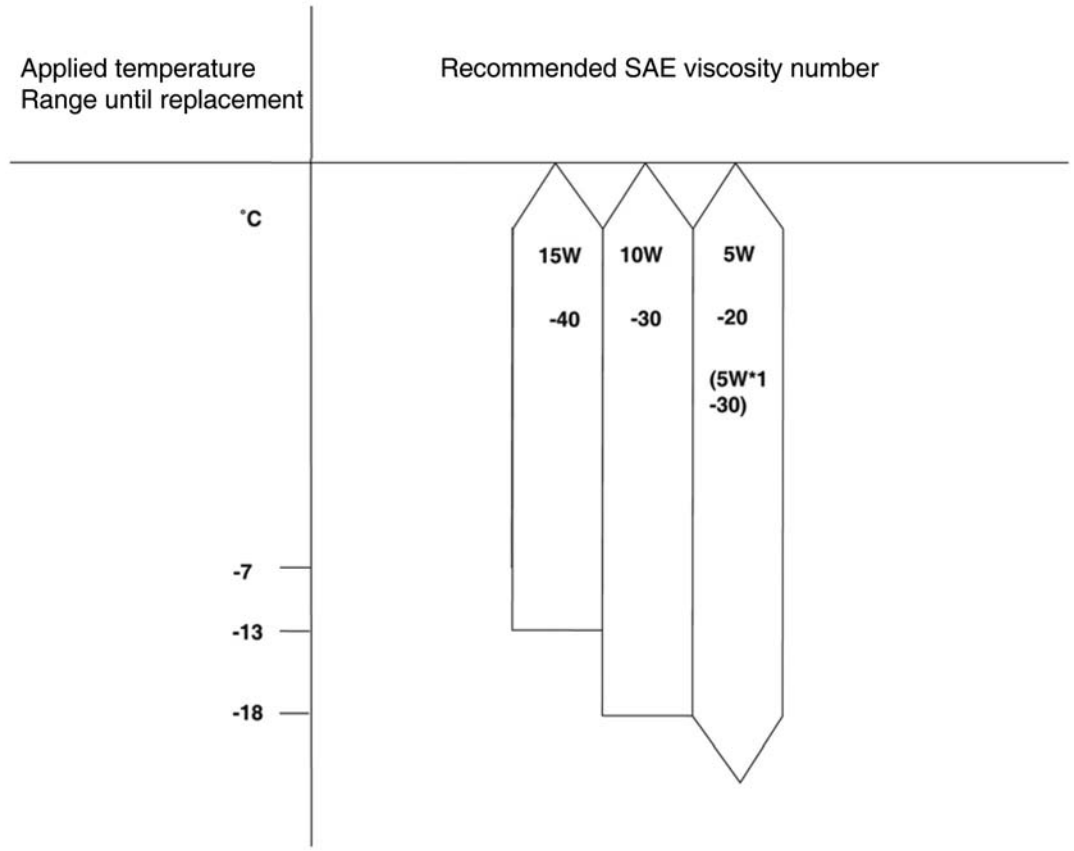
- Check for loose, dirty or damaged connectors and wires on the harness including: fuel lock-off, TMAP sensor, O2 sensors, electronic throttle, control relays, fuel trim valves, crank position sensor, and cam position sensor.
- Repair and/or replace as necessary.

Inspect Foot Pedal Operation

- Verify foot pedal travel is smooth without sticking.

Engine Oil Classification

Recommended API classification: Above SJ
Recommended SAE viscosity classification



*1. 10W-30 engine oil is recommended
If 10W-30 is not applicable, proper engine oil will be possible according to temperature ranges.

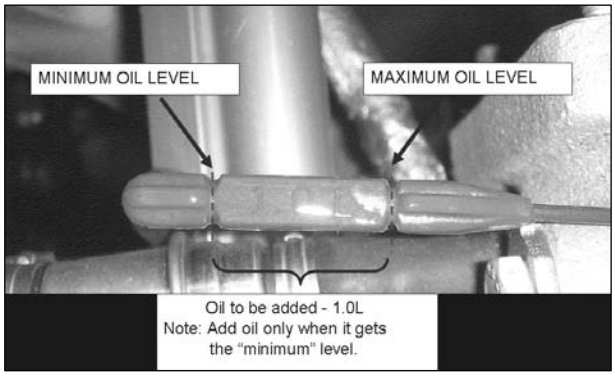
L4GC209A

The following lubricants should be selected for all engines to enhance excellent performance and maximum effect.

1. Observe the API classification guide.

2. Proper SAE classification number should be selected within ambient temperature ranges. Do not use the lubricant with SAE classification number and API grade not identified on the container.

Checking Engine Oil Level



1. Check that the oil level is between “MIN” and “Max” marks on the engine oil level gauge.

2. If the oil level is below “MIN” mark, add oil until the level is within the specified ranges.

3. Check the engine for oil contamination and viscosity and replace if necessary.

Replacing Engine Oil and Filter

⚠ CAUTION

Prolonged and repeated contact with mineral oil will result in the removal of natural fats from the skin, leading to dryness, irritation and dermatitis. In addition, used engine oil contains potentially harmful contaminants which may cause skin cancer.
Exercise caution in order to minimize the length and frequency of contact of your skin to used oil. In order to preserve the environment, used oil and used oil filter must be disposed of only at designated disposal sites.

1. Drain engine oil.

1) Remove the oil filler cap.

2) Remove the oil drain plug, and drain the oil into a container.

2. Replace oil filter.

1) Remove the oil filter.

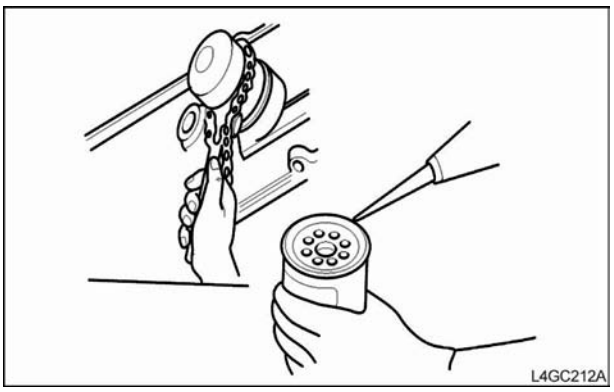
2) Check and clean the oil filter installation surface.

3) Check the part number of the new oil filter is as same as old one.

4) Apply clean engine oil to the gasket of a new oil filter.

5) Lightly screw the oil filter into place, and tighten it until the gasket contacts the seat.

6) Tighten it an additional 3/4 turn.



3. Refill with engine oil filter.

1) Clean and install the oil drain plug with a new gasket.

Torque	40~70 N·m

2)Fill with fresh engine oil.

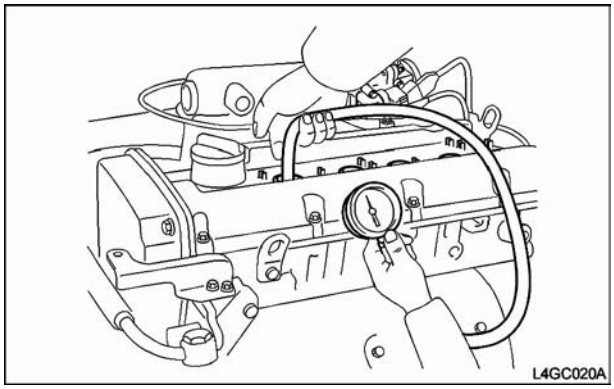
Capacity Drain and refill	4.3 L
Oil filter	0.3 L

3) Install the oil filler cap.

4. Start engine and check for oil leaks.

5. Recheck engine oil level.

Checking Compressed Pressure



1. Prior to inspection, check that the engine oil, starter motor and battery are normal.

2. Start the engine and run it until the engine coolant temperature reaches 80 ~ 95°C.

3. Stop the engine and disconnect the ignition coil and air cleaner element.

4. Remove the spark plug.

5. After opening the throttle valve completely, crank the engine to remove foreign material from the cylinder.

⚠ CAUTION

At this time, necessarily screen the spark plug hole with a rag. Because hot coolant, oil, fuel, and other foreign material, being penetrated in the cylinder through cracks can come into the spark hole during checking compressed pressure.
When cranking the engine to test compressed pressure, necessarily open the throttle valve before cranking.

6. Install the compression gauge to the spark plug hole.

7. With the throttle valve opened, crank the engine to measure the compressed pressure.

Standard (250~400 rpm)	Limit	1,240 kPa

8. Repeat steps (no.6-7) over all cylinders, ensuring that the pressure differential for each of the cylinders is within the limit.

Limit	100 kPa (between cylinders)

9. If any of all cylinders is out of limit, add a small amount of engine oil to the spark plug hole, and re-proceed the procedures (no.6-7) to the cylinder.

At this time, if the compressed pressure is increased, it means that the piston, piston ring or cylinder surface are worn or damaged, and if the compressed pressure is decreased, it means that the valve is clogged, the valve contact is faulty, or the pressure leaks through gasket.

⚠ CAUTION

If a large amount of incomplete combustion gasoline comes into the catalytic converter, emergency such as a fire can occur due to overheating. So this job should be done quickly with the engine not operated.

Cooling System Maintenance

Coolant Recommendation

The engine cooling system is provided with a mixture of 50% ethylene glycol anti-freeze and 50% water (For the vehicles of tropical area, the engine cooling system is provided with a mixture of 40% ethylene glycol anti-freeze and 60% water at the time of manufacture.)
Since the cylinder head and water pump body are made of aluminum alloy casting, be sure to use a 30 to 60% ethylene glycol antifreeze coolant to assure corrosion protection and freezing prevention.

⚠ CAUTION

If the concentration of the antifreeze is below 30%, the anticorrosion property will be adversely affected. In addition, if the concentration is above 60%, both the antifreeze and engine cooling properties will decrease, adversely affecting the engine. For these reasons, be sure to maintain the concentration level within the specified range.

Coolant Water

Hard water, or water with high levels of calcium and magnesium ions, encourages the formation of insoluble chemical compounds by combining with cooling system additives such as silicates and phosphates.

The tendency of silicates and phosphates to precipitate out-of-solution increases with increasing water hardness. Hard water, or water with high levels of calcium and magnesium ions encourages the formation of insoluble chemicals, especially after a number of heating and cooling cycles.

DOOSAN prefers the use of distilled water or deionized water to reduce the potential and severity of chemical insolubility.

Acceptable Water	
Water Content	Limits (ppm)
Chlorides (CI)	40 maximum
Sulfates (SO4)	50 maximum
Total Hardness	80mg/ℓ maximum
Total Solids	250 maximum
pH	6.0 ~ 8.0

ppm = parts per million

Antifreeze

DOOSAN recommends selecting automotive antifreeze suitable for gasoline engines using aluminum alloy parts. The antifreeze should meet ASTM-D3306 standard.

Check Coolant Level

- The items below are a general guideline for system checks. Refer to the engine manufacturer's specific recommendations for proper procedures.
- Engine must be off and cold.

⚠ WARNING—PROPER USE

Never remove the pressure cap on a hot engine.

- The coolant level should be equal to the "COLD" mark on the coolant recovery tank.
- Add approve coolant to the specified level if the system is low.

Inspect Coolant Hoses

- Visually inspect coolant hoses and clamps. Remember to check the two coolant lines that connect to the pressure regulator/converter.
- Replace any hose that shows signs of leakage, swelling, cracking, abrasion or deterioration.

Checking coolant leaks

1. After the coolant temperature drops below 38°C loosen the radiator cap.

2. Check that the coolant level reaches filler neck.

3. Install the radiator cap tester to the radiator filler neck and apply a pressure of 1.4kg/cm2 .
While maintaining it for 2 minutes, check the radiator, hose, and connecting part for leak.

⚠ CAUTION

Because the coolant in the radiator is too hot, never open the cap when it hot, or injury may occur due to an outburst of hot water.
Dry out the inspection part.
When removing the tester, take care not to spill the coolant.
When removing/installing the tester as well as testing, take care not to deform the filler neck.

4. Replace parts if leak is detected.

Specific gravity test

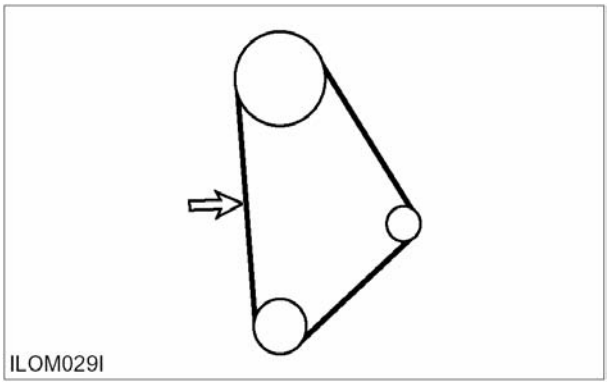
1. Measure specific gravity of the coolant using a hydrometer.

2. After measuring the coolant temperature, calculate specific gravity using the following table.

Relation between Coolant concentration and Specific Gravity

Temperature and Specific gravity of coolant (Temp.:℃)					Freezing temp(℃)	Coolant Concentration Specific Volume
10	20	30	40	50		
1.054	1.050	1.046	1.042	1.036	-16	30%
1.063	1.058	1.054	1.049	1.044	-20	35%
1.071	1.067	1.062	1.057	1.052	-25	40%
1.079	1.074	1.069	1.064	1.058	-30	45%
1.087	1.082	1.076	1.070	1.064	-36	50%
1.095	1.090	1.084	1.077	1.070	-42	55%
1.103	1.098	1.092	1.084	1.076	-50	60%

Checking and Adjusting Drive Belt



1. Checking tension

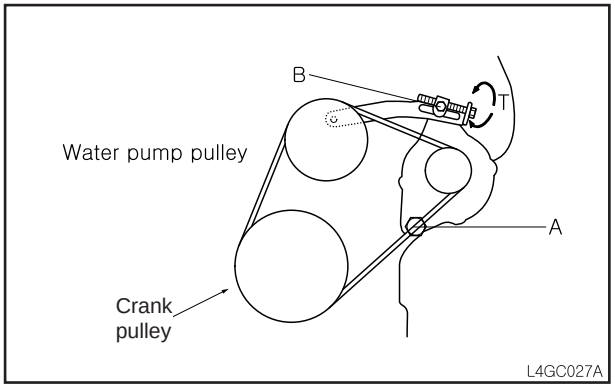
1) Press the middle of the water pump pulley and alternator pulley with 10kgf.

2) Inspect the belt deflection by pressing it.

3) If the belt deflection is out of the standard, adjust it as follows.

Item	Standard	
	New belt	Used belt
Drive belt deflection (L)	4.0~4.4mm	5.1~5.7mm

Adjusting



1. Loosen the alternator support bolt “A” nut and adjusting lock bolt “B”.

2. Adjust the belt tension by moving the alternator brace adjusting bolt to “T” direction.

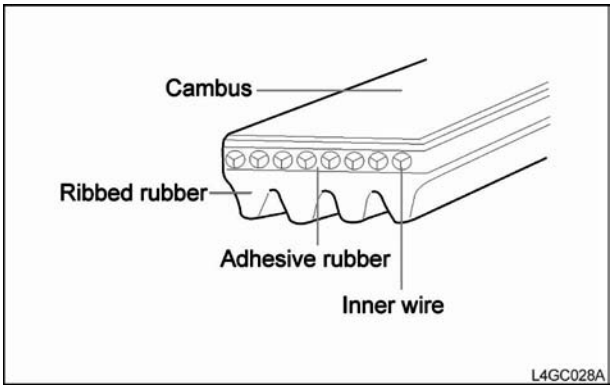
Alternator adjusting lock bolt “B”	1.2~1.5kg·m
Alternator support bolt “A”	2~2.5kg·m

3. Tighten the bolt “A” and then tighten “B” to the specified torque.

⚠ CAUTION

If the belt tension is too excessive, noise as well as early wear of belt occurs and the water pump bearing and alternator bearing are damaged.
If the belt is too loose, due to early wear of belt and insufficient power of alternator, battery and water pump become inefficient and finally engine is overheated or damaged.

Checking Belt for Damage



Check the following items and replace the belt if defective.

1. Check the belt surface for damage, wear and crack.

2. Check the belt surface for oil or grease contamination.

3. Check the rubber part for wear or hardening.

4. Check the pulley surface for crack or damage.

Ignition System Maintenance

Inspect Battery System

- Clean battery outer surfaces with a mixture of baking soda and water.
- Inspect battery outer surfaces for damage and replace as necessary.
- Remove battery cables and clean, repair and/or replace as necessary.

Inspect Ignition System

- Remove and inspect the spark plugs. Replace as required.
- Inspect the ignition coil for cracks and heat deterioration. Visually inspect the coil heat sink fins. If any fins are broken replace as required.

Inspection of Ignition Timing

1. Inspection condition

Coolant temperature : 80-90°C(At normal Temperature)

Lamp and all accessories : OFF

Transmission : In neutral position

Parking brake : ON

2. Inspection

1) Connect the timing light.

2) Measure RPM.

RPM

Low Idle	750±15rpm

NOTE: If RPM is not normal, it is impossible to measure the proper ignition timing, so measure it at a normal RPM.

3) Inspect the standard ignition timing.

BTDC	5˚±5˚

4) If ignition timing is out of the standard, inspect sensors concerned with ignition timing.

⚠ CAUTION

Because ignition timing is fixed by set data value in ECU, it is impossible to control on purpose.
Fist, check that sensors send output properly to help determine ignition timing control.

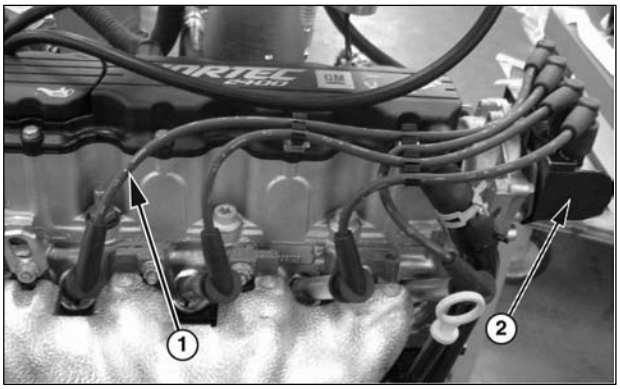
NOTE: Affective ECU input to Ignition timing control

- Coolant temperature sensor
- Oxygen sensor
- Battery voltage
- MAP sensor (Engine load)
- Crankshaft position sensor
- Throttle position sensor
- Intake Air Temperature sensor

5) Check that actual ignition timing is changed with engine RPM increased.

Inspection of Spark Plug

Inspection and clean



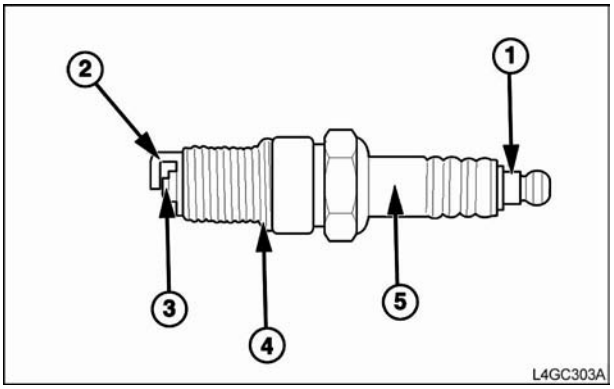
1) Ignition cable
2) Ignition coil

1. Disconnect the ignition cables from ignition coil ass'y.

2. Remove all spark plugs from the cylinder head using a sparkplug wrench.

⚠ CAUTION

Take care not to come foreign materials into spark-plug mounting hole.



3. Check the spark plug as below.

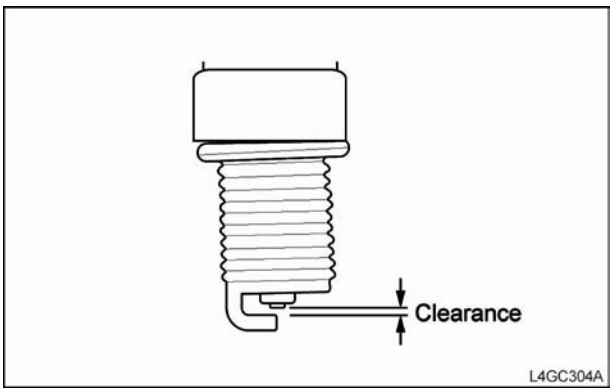
1) Insulator broken

2) Terminal worn

3) Carbon deposit

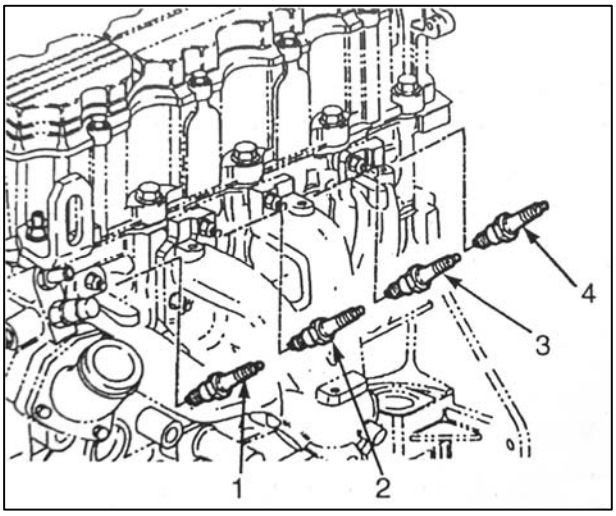
4) Gasket damaged or broken

5) Porcelain insulator of spark plug clearance



4. Check the plug clearance using a plug clearance gauge and if the value is not within the specified values, adjust it by bending the ground clearance. When installing a new sparkplug, install it after checking the uniform plug clearance.

Spark plug clearance	0.8~0.9mm



Spark Plugs

5. Install the spark plug and tighten it to the specified torque.
Take care not to over tighten it to prevent cylinder head threads from damage.

Tightening torque	2 ~ 2.5 kg·m

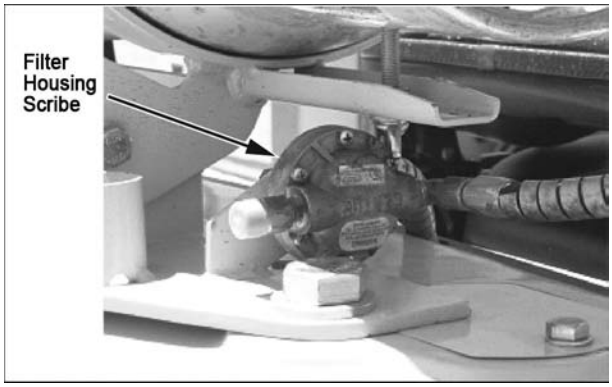
SPARK PLUG ANALYSIS

State	Contact point is black	Contact point is white
Description	• Density of the fuel mixture is thick • Lack of air intake	• Density of the fuel mixture is thin • Ignition timing is fast • Spark plug is tight • Lack of torque

Fuel System Maintenance

Replace LP Fuel Filter Element

Park the lift truck in an authorized refueling area with the forks lowered, parking brake applied and the transmission in Neutral.

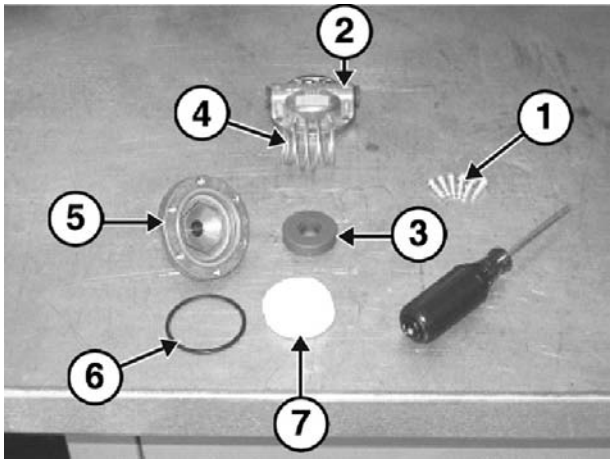


1. Close the fuel shutoff valve on the LP-fuel tank. Run the engine until the fuel in the system runs out and the engine stops.

2. Turn off the ignition switch.

3. Scribe a line across the filter housing covers, which will be used for alignment purposes when re-installing the filter cover.

FUEL FILTER DISASSEMBLY (Steps 4-7)



4. Remove the cover retaining screws (1).

5. Remove top cover (2), magnet (3), spring (4), and filter element (7) from bottom cover (5).

6. Replace the filter element (7).

7. Check bottom cover O-ring seal (6) for damage. Replace if necessary.

8. Re-assemble the filter assembly aligning the scribe lines on the top and bottom covers.

9. Install the cover retaining screws, tightening the screws in an opposite sequence across the cover.

10. Open the fuel valve by slowly turning the valve counterclockwise.

11. Crank the engine several revolutions to open the fuel lock-off. DO NOT START THE ENGINE. Turn the ignition key switch to the off position.

12. Check the filter housing, fuel lines and fittings for leaks. Repair as necessary.

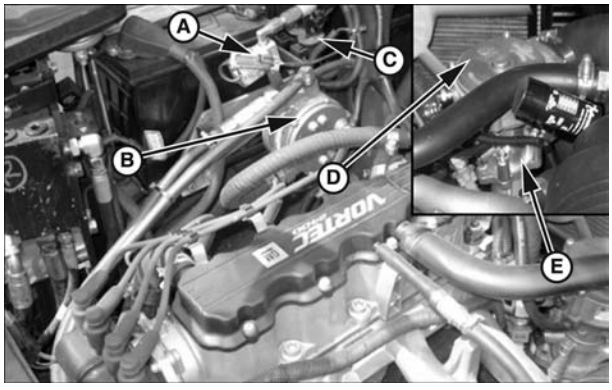
Testing Fuel Lock-off Operation

- Start engine.
- Locate the electrical connector for the fuel lock (A).
- Disconnect the electrical connector.
- The engine should run out of fuel and stop within a short period of time.

NOTE

The length of time the engine runs on trapped fuel vapor increases with any increase in distance between the fuel lock-off and the pressure regulator/converter.

- Turn the ignition key switch off and re-connect the fuel lock-off connector.



Pressure Regulator/Converter Inspection

- Visually inspect the pressure regulator/converter (B) housing for coolant leaks.

- Refer to Chapter 5 if the pressure regulator/converter requires replacement.

Fuel Trim Valve Inspection (FTV)

- Visually inspect the fuel trim valves (C) for abrasions or cracking. Replace as necessary.

- To ensure a valve is not leaking a blow-by test can be performed.

1. With the engine off, disconnect the electrical connector to the FTVs.

2. Disconnect the vacuum line from the FTVs to the pressure regulator/converter at the converter's tee connection.

3. Lightly blow through the vacuum line connected to the FTVs.
Air should not pass through the FTVs when de-energized.
If air leaks past the FTVs when de-energized, replace the FTVs.

Inspect Air/Fuel Valve Mixer Assembly

- Refer to Chapter 5 for procedures regarding the LP mixer (D).

Inspect for Intake Leaks

- Visually inspect the intake throttle assembly (E), and intake manifold for looseness and leaks. Repair as necessary.

Inspect Throttle Assembly

- Visually inspect the throttle assembly motor housing for coking, cracks, and missing cover-retaining clips. Repair and/or replace as necessary.

NOTE: Refer to Chapter 5 for procedures on removing the mixer and inspecting the throttle plate.

Checking the TMAP Sensor

- Verify that the TMAP sensor (F) is mounted tightly into the manifold or manifold adapter (E), with no leakage.

- If the TMAP is found to be loose, remove the TMAP retaining screw and the TMAP sensor from the manifold adapter.

- Visually inspect the TMAP O-ring seal for damage. Replace as necessary.

- Apply a thin coat of an approved silicon lubricant to the TMAP O-ring seal.

- Re-install the TMAP sensor into the manifold or manifold adapter and securely tighten the retaining screw.

Exhaust System Maintenance

Inspect Engine for Exhaust Leaks

- Start the engine and allow it to reach operating temperatures.

- Perform visual inspection of exhaust system from the engine all the way to the tailpipe. Any leaks, even after the post-catalyst oxygen sensor, can cause the sensor output to be effected (due to exhaust pulsation entraining air upstream). Repair any/all leaks found. Ensure the length from the post-catalyst sensor to tailpipe is the same as original factory.

- Ensure that wire routing for the oxygen sensors is still keeping wires away from the exhaust system. Visually inspect the oxygen sensors to detect any damage.

Maintenance Schedule

NOTE: The MI-07 fuel system was designed for use with LPG fuel that complies with HD5 or HD10 LPG fuel standards. Use of non-compliant LPG fuel may require more frequent service intervals and will disqualify the user from warranty claims.

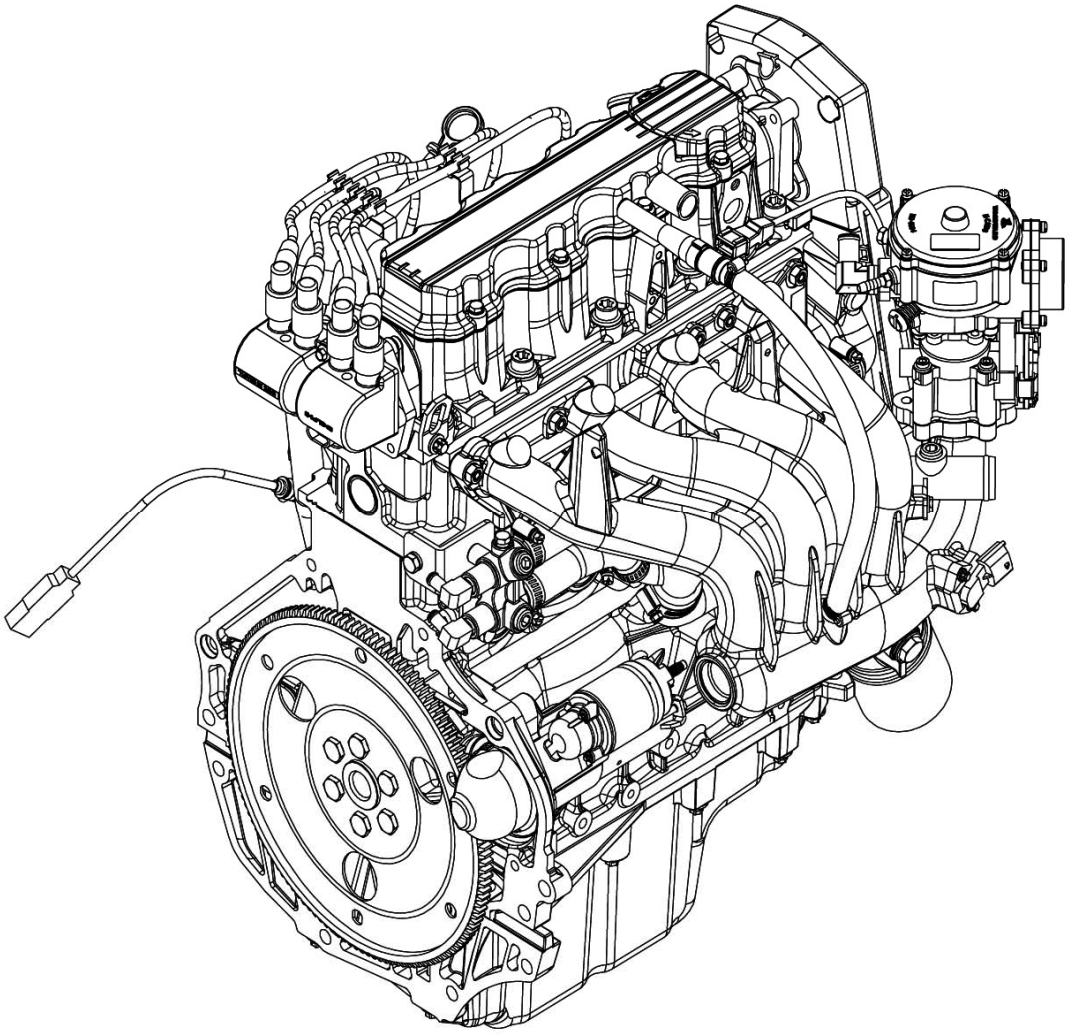
CHECK POINT	INTERVAL HOURS						
	Daily	Every 250 Hours or 1 month	Every 500 Hours or 3 months	Every 1000 Hours or 6 months	Every 1500 Hours or 9 months	Every 2500 Hours or 15 months	Every 3000 Hours or 18 months
General Maintenance							
Test fuel system for leaks.	Prior to any service or maintenance activity						
Inspect engine for fluid leaks.	X						
Inspect all vacuum lines and fittings.			X				
Inspect electrical system; check for loose, dirty, or damaged wires and connections.			X				
Inspect isolation mounts on engine control module for cracks and wear; replace as necessary.			X				
Inspect all fuel fittings and hoses.				X			
Inspect foot pedal travel and operation.	X						
Replace timing belt							X
Check for MIL lamp test at key-on. If MIL lamp remains illuminated (indicating a fault), use pedal to recover fault code(s). Repair faults.	X						
Engine Coolant							
Check coolant level.	X						
Inspect coolant hoses and fittings for leaks, cracks, swelling, or deterioration.				X			
Engine Ignition							
Inspect battery for damage and corroded cables.						X	
Inspect ignition system.					X		
Replace spark plugs					X		
Fuel Lock-Off/Filter							
Replace LP fuel filter element.					X		
Inspect lock-off and fuel filter for leaks.				X			
Ensure lock-off stops fuel flow when engine is off.				X			

CHECK POINT	INTERVAL HOURS						
	Daily	Every 250 Hours or 1 month	Every 500 Hours or 3 months	Every 1000 Hours or 6 months	Every 1500 Hours or 9 months	Every 2500 Hours or 15 months	Every 3000 Hours or 18 months
Pressure Regulator/Converter							
Test regulator pressures.				X			
Inspect pressure regulator vapor hose for deposit build-up. Clean or replace as necessary.				X			
Inspect regulator assembly for fuel/coolant leaks.				X			
Fuel Trim Valve (G420FE only)							
Inspect valve housing for wear, cracks or deterioration.				X			
Ensure valve seals in the closed position when the engine is off.				X			
Replace FTV.	When indicated by MIL						
Carburetor (Mixer)							
Check air filter indicator.	X						
Check for air leaks in the filter system.				X			
Inspect air/fuel valve mixer assembly for cracks, loose hoses, and fittings. Repair or replace as necessary.			X				
Check for vacuum leaks in the intake system including manifold adapter and mixer to throttle adapter.						X	
Repair or replace throttle assembly.	When indicated by MIL						
Inspect air filter.			X				
Replace air filter element.				X			
Check TMAP sensor for tightness and leaks.						X	
Exhaust & Emission							
Inspect engine for exhaust leaks.	X						
Replace PCV valve and breather element.						X	
Replace HEGO sensors	When indicated by MIL						
Gasoline Engines							
Replace gasoline fuel filter element.						X	
Inspect gasoline fuel system for leaks.						X	
Confirm gasoline supply pressure is correct.	Pressure should be 45-55 psig (310-379 kPa)						

Chapter 3. ENGINE MECHANICAL SYSTEM

General Information

Engine Outline



Technical Specifications

CRANKSHAFT

Maximum saddle taper ..... 0.005 mm

Maximum saddle out-of-roundness ..... 0.004 mm

Crankshaft maximum warping ..... 0.03 mm

Trunnion diameter ..... 57.9820 – 57.9950 mm

Journal diameter ..... 48971 – 49987 mm

Maximum clearance between trunnion and shell ..... 0.015 – 0.041 mm

Clearance between journal and connecting rod shell ..... 0.012 – 0.062 mm

Connecting rod journal end clearance ..... 0.070 – 0.242 mm

Reboring number 2

Crankshaft end clearance ..... 0.02 – 0.352 mm

Shells: See color definitions below, under “Table of Spare Shells”

CYLINDERS AND PISTONS

Clearance between piston and cylinder (skirt lower area) ..... 0.010 a 0.030 mm

Maximum saddle out-of-roundness ..... 0.127 mm

Crankshaft maximum warping ..... 0.127 mm

Piston stroke ..... 100 mm

Piston bore ..... 87.5 mm

Distance between piston head in the TDC and block surface ..... 0.11 a 0.43 mm

Angle between the compression ring openings ..... 100°

Gap between compression ring tips ..... 1st groove 0.25 – 0.45
..... 2nd groove 0.15 – 0.45

Gap between compression rings and grooves

– Upper groove ..... 0.005 – 0.085

– Lower groove ..... 0.035 – 0.008

Gap between the oil scraper-type control oil ..... 0.20 – 0.55

CYLINDER HEAD

Valve seat angle (all) ..... 90° ± 1°

INTAKE AND EXHAUST VALVES

Seat angle ..... 92° ± 15°

Stem lash in the guides..... 0.015 a 0.042 mm (intake)
e 0.030 a 0.060 mm (exhaust)

Available oversize..... 0.075 a 0.150 e 0.250 mm

Valve seat eccentricity tolerance (between maximum and minimum readings)..... 0.050 mm

Valve seat widths:

– Intake.....1.3 – 1.4 mm

– Exhaust .....1.7 – 1.8 mm

CAMSHAFT

End clearance.....0.04 – 0.16 mm

Camshaft maximum warping..... 0.04 mm

OIL PUMP

Clearance between:

– Driven gear and case .....0.11 a 0.19 mm

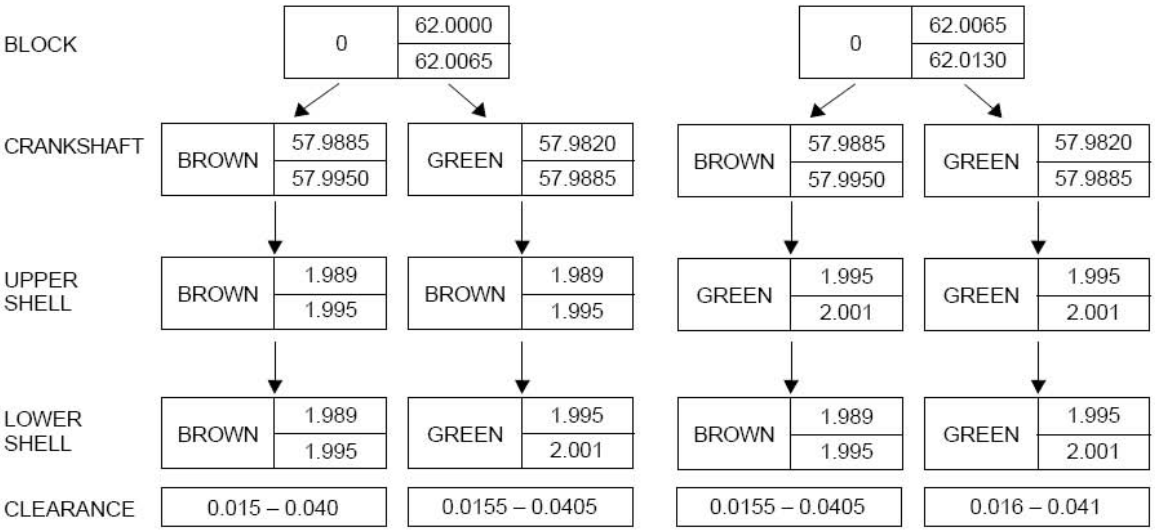
– Drive gear and crescent.....0.35 a 0.45 mm

– Gear and cover.....0.03 a 0.10 mm

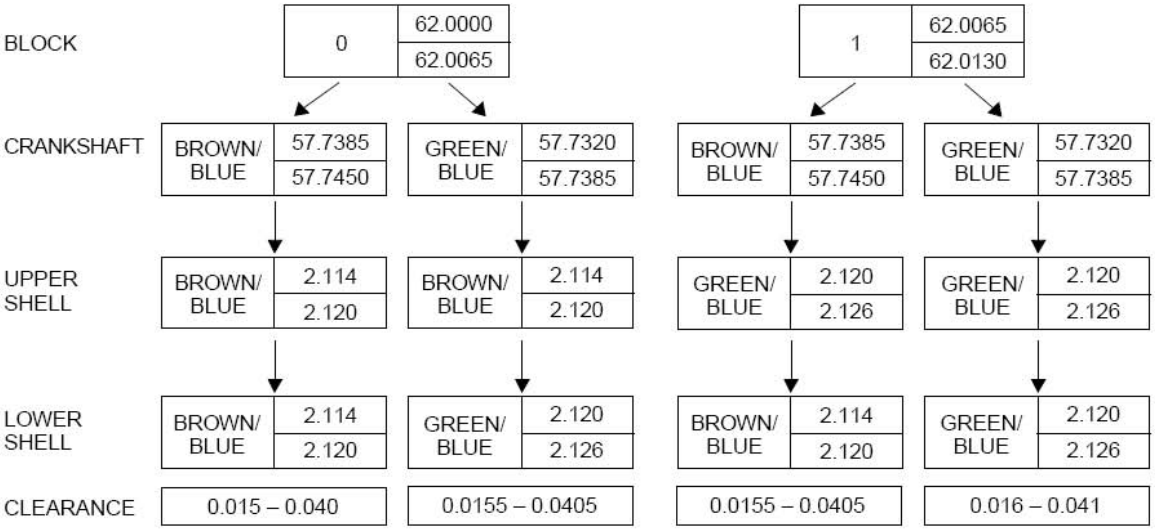
Pressure @ 1400 RPM.....282 – 324 kPa
(41 – 47 lbf·pul²)

Shells Selection Table

MAIN BEARINGS – STANDARD SIZE (*)

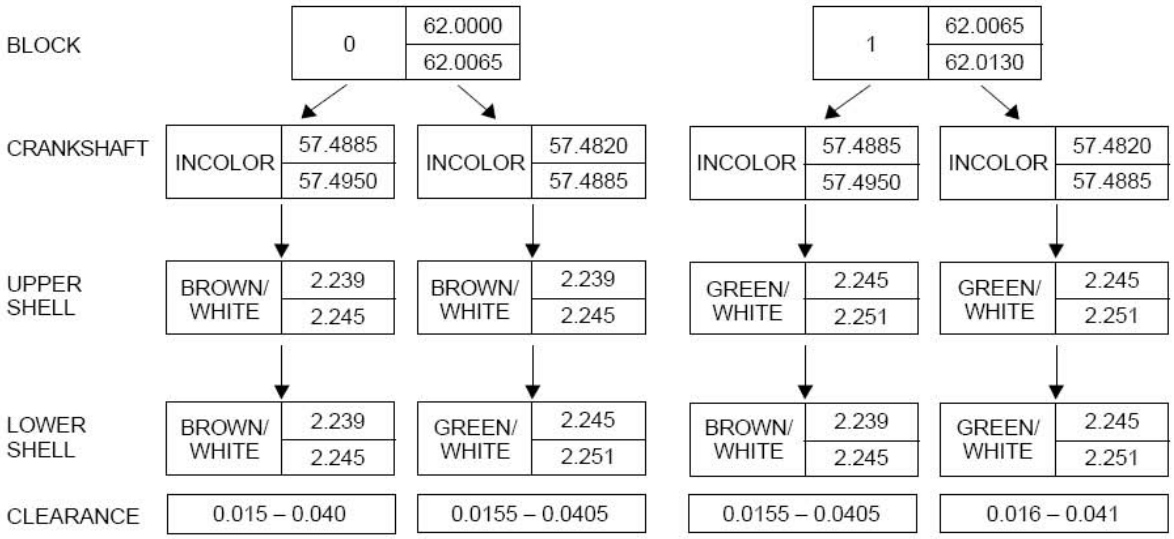


MAIN BEARINGS – 0.25 OVERSIZE (*)



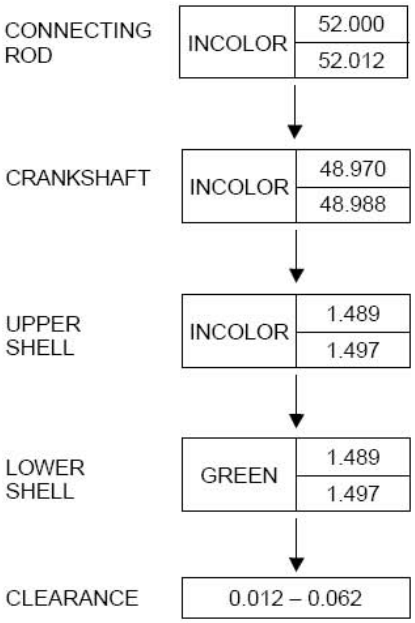
(*) ALL MEASURES ARE IN MILLIMETERS

MAIN BEARINGS – 0.50 UNDERSIZE (*)

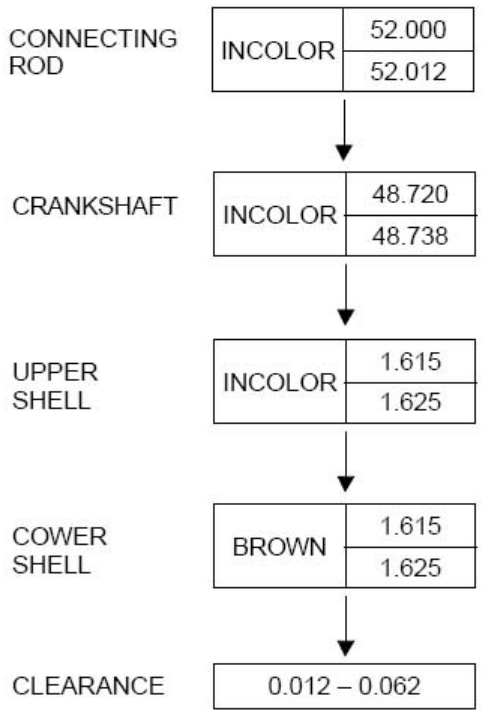


(*) ALL MEASURES ARE IN MILLIMETERS

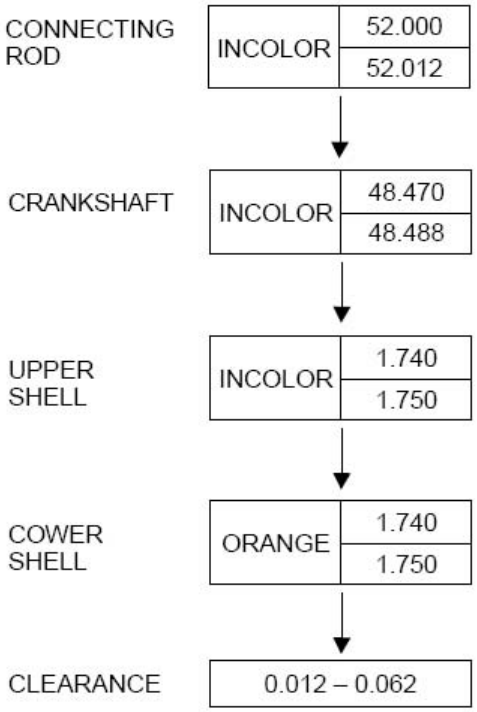
MAIN BEARINGS – STANDARD SIZE



CONNECTING ROD BEARINGS
0.25 UNDERSIZE



CONNECTING ROD BEARINGS
0.50 UNDERSIZE



Recommended Torque Values

nuts	**N•m**
Starter to cylinder block	45
Exhaust manifold to cylinder head	18-22 1)
Dipstick oil tube to cylinder block	20-30
DIS Ignition Module to camshaft housing carrier	8
Throttle body to intake manifold	11-13
Pressure plate to camshaft housing	8
Intake manifold to cylinder head	18-22 1)
Crankshaft position sensor	6
Rear toothed belt cover bolts	8
Rear toothed belt cover nuts	7
Heat shield to exhaust manifold	6-8
bolts	**N•m**
V–belt tensioner to alternator support	25
Fuel distributor tube to intake manifold	22-30
Fuel supply and return line to throttle valve guards	15
Water pump to cylinder block	25
Coolant pipe to cylinder block	20
Crankshaft main bearing cap to cylinder block	50 N•m + 45° + 15°
Oxygen sensor to exhaust manifold	35-44
Crankcase oil baffle plate and bridge bolts	20
Camshaft housing cover to camshaft housing	8
Camshaft sprocket to camshaft	45
Oil drain bolt to oil pan	40-70
Oil pressure switch to oil pump	30-50
Oil filter to oil pump	Hand Tight
Oil pump to cylinder block	10
Oil pump cover to oil pump	6
Oil intake pipe to oil pump	10
Oil intake pipe to cylinder block	8
Oil baffle plate to oil pan	8
Oil pan to transmission	40

bolts	N•m
Oil pan to cylinder block	18-22
Con–rod bearing cap to con–rod	30-40+40°+45°
Flywheel to crankshaft	35 + 30 ° + 15° 2)
Coolant temperature sensor to thermostat housing	20
Thermostat housing to cylinder head	15
Carrier plate (DIS ignition module) to camshaft housing	12
Relief valve plug to oil pump	45 - 60
Toothed belt cover, lower part to rear toothed belt cover	4
Toothed belt tension roller to oil pump	20
Spark plug to cylinder head	25
Cylinder head and camshaft housing to cylinder block	25 + 180°+ 10° 2)

1. Use new nuts.

2. Use new bolts.

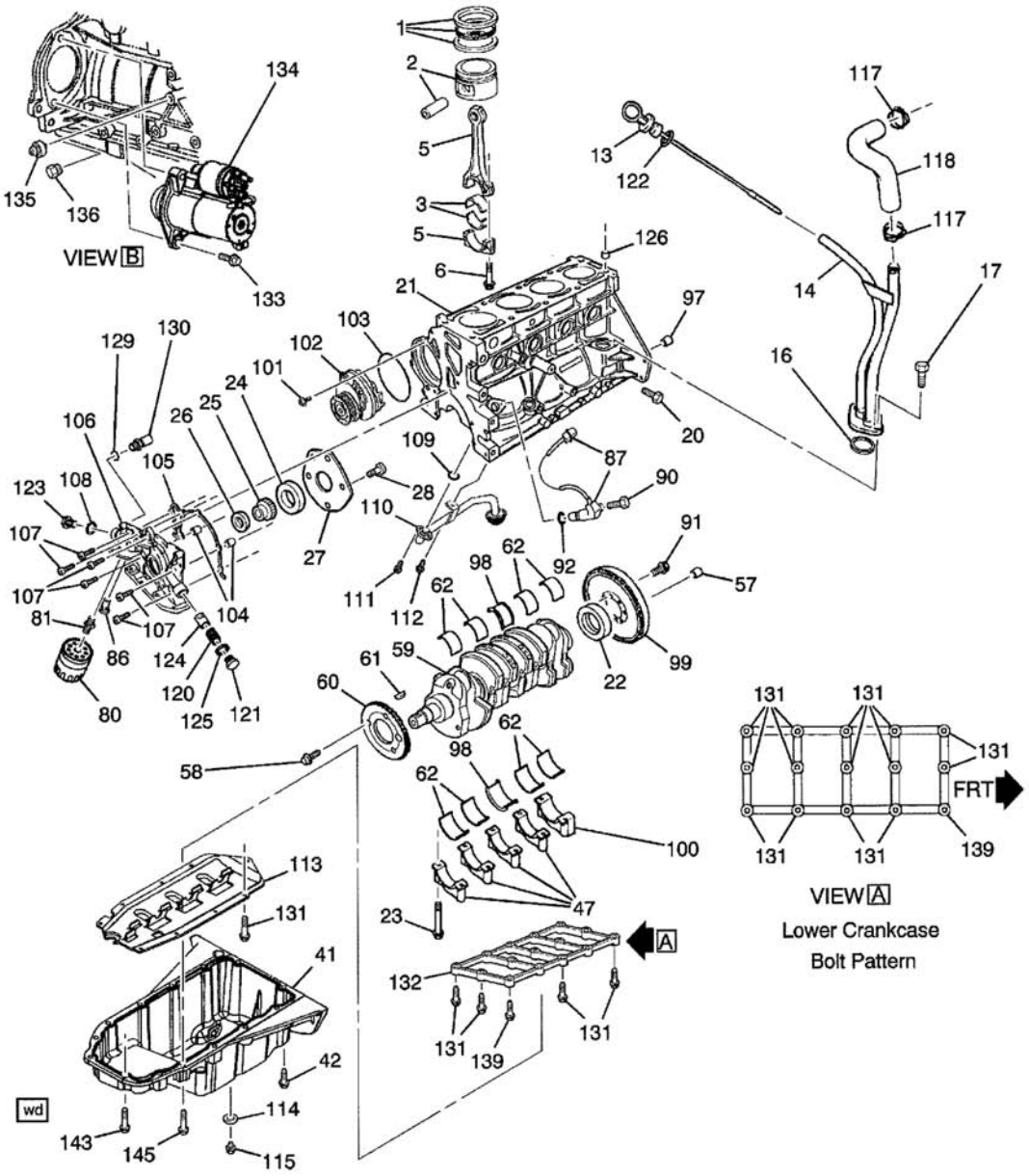
3. Rectum thread before reuse and insert bolts with screw locking compound (red). The installation time including the torque check is maximum 10 minutes.

4. Insert bolts with mounting paste (white).

Troubleshooting

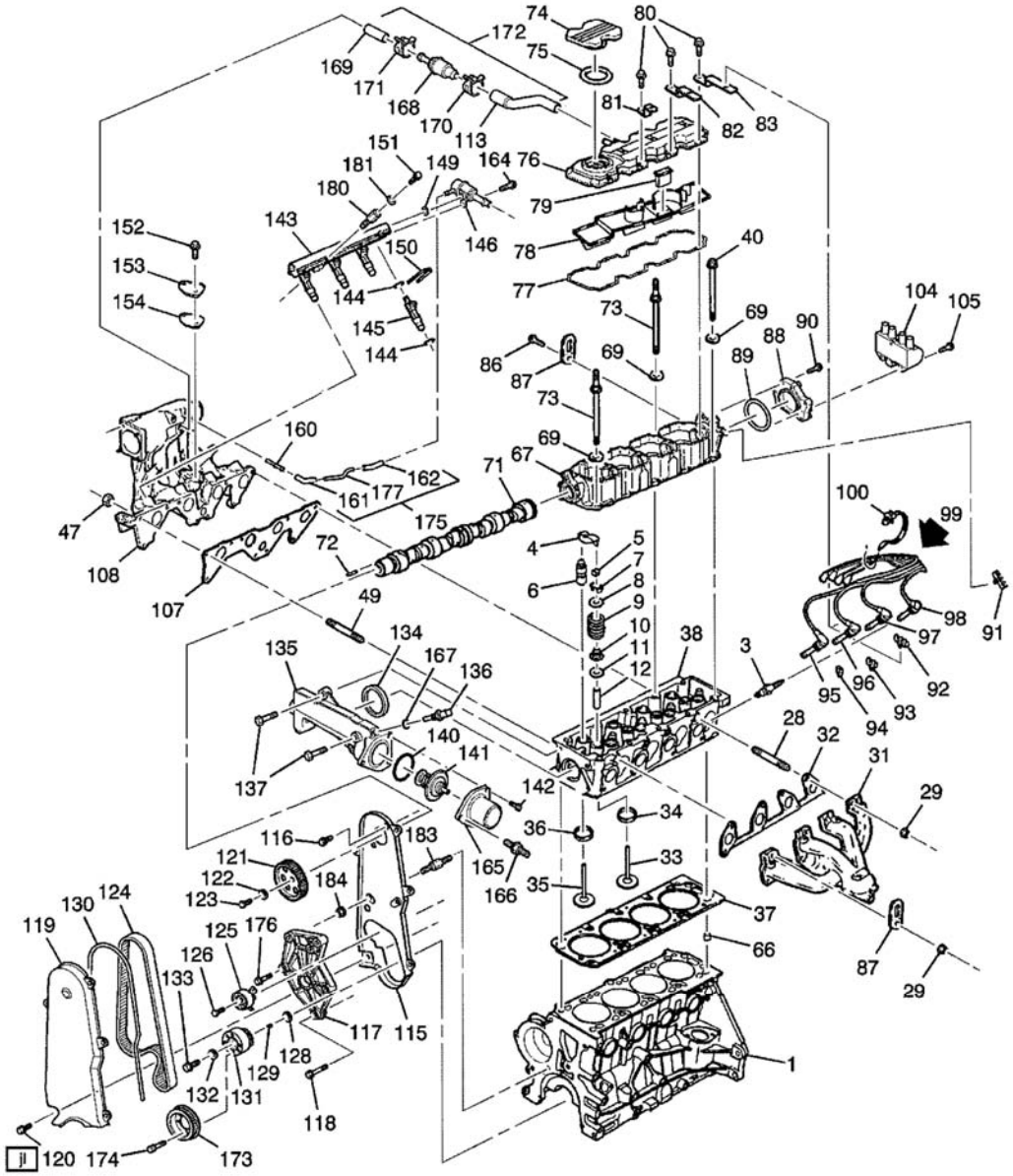
Symptom	Possible cause	Remedy
Low compression	Cylinder head gasket damaged Worn or damaged piston ring Worn piston or cylinder Worn or damaged valve seat	Replace gasket Replace ring Repair or replace piston and cylinder block Repair or replace valve and seat ring
Low oil pressure	Insufficient engine oil Oil pressure switch defective Oil filter clogged Worn oil pump gear or cover Thin or diluted engine oil Oil relief valve clogged(Open) Excessive bearing clearance	Check engine oil level Replace oil pressure switch Install new filter Replace Replace engine oil Replace or inspect Replace bearing
High oil pressure	Oil relief valve clogged(Closed)	Repair relief valve
Noisy valve	Thin or diluted engine oil Faulty HLA Worn belt stem or valve guide	Replace engine oil Replace HLA Replace belt stem or valve guide
Noisy connecting rod or timing belt	Insufficient engine oil Low oil pressure Thin or diluted engine oil Excessive bearing clearance	Check engine oil level Refer to too low oil pressure Replace engine oil Replace bearing
Noisy timing belt	Incorrect belt tension	Correct belt tension
Low coolant level	Coolant leak from Heater or radiator hose Defective radiator cap Thermostat housing Radiator Water pump	Repair or replace parts Retighten clamp or replace Replace gasket or housing Replace Replace parts
Radiator clogged	Foreign material into coolant	Replace coolant
Abnormally high coolant temperature	Thermostat defective Radiator cap defective Abnormal flow in cooling system Loose or missing driving belt Loose water pump Water temperature wiring defective Cooling pan defective Radiator or thermostat switch defective Inefficient coolant	Replace parts Replace parts Clean or replace parts Correct or replace Replace Repair or replace Repair or replace Replace Add coolant
Abnormally low coolant temperature	Thermostat defective Water wiring defective	Replace Repair or replace
Oil cooling system leak	Loose connecting part Cracked or damaged hose, pipe, and oil cooler	Retighten Replace
Exhaust gas leak	Loose connecting part Pipe or muffler damaged	Retighten Repair or replace
Abnormal noise	Breakaway exhaust plate in muffler Rubber hanger damaged Pipe or muffler with body Interfered Pipe or muffler damaged Catalytic converter damaged Each connecting gasket damaged	Replace Replace Repair Repair or replace Replace Replace

Engine Exploded View (1 of 2)



1) RING KIT	2) PISTON	3) BEARING KIT	5) ROD	6) BOLT
13) INDICATORK,OIL LVL	14) HOSE	16) GASKET	17) BOLT	20) PLUG
21) ENGINE	22) SEAL	23) BOLT	24) GEAR	25) GEAR
26) SEAL	27) COVER	28) BOLT	41) PAN,OIL	42) BOLT
47) CAP	57) BEARING	58) BOLT	59) CRANKSHAFT	60) RING
61) KEY	62) BEARING KIT	80) FILTER	81) FITTING	86) VALVE
87) SENSOR	90) BOLT	91) BOLT	92) SEAL	97) PIN
98) BEARING KIT	99) PLATE	100) CAP	101) BOLT	102) PUMP
103) SEAL	104) PIN	105) GASKET	106) PUMP	107) BOLT
108) SEAL	109) SEAL	110)PIPE	111) BOLT	112) BOLT
113) BAFFLE	114) SEAL	115) PLUG	117) CLAMP	118) HOSE
120) SPRING	121) PLUG	122) SEAL	123) PLUG	124) VALVE
125) GASKET	126) PIN	129) SEAL	130) SWITCH	131) BOLT
132) PLATE	133) BOLT	134) STARTER	135) SENSOR	136) PLUG
139) BOLT	143) BOLT	145) BOLT		

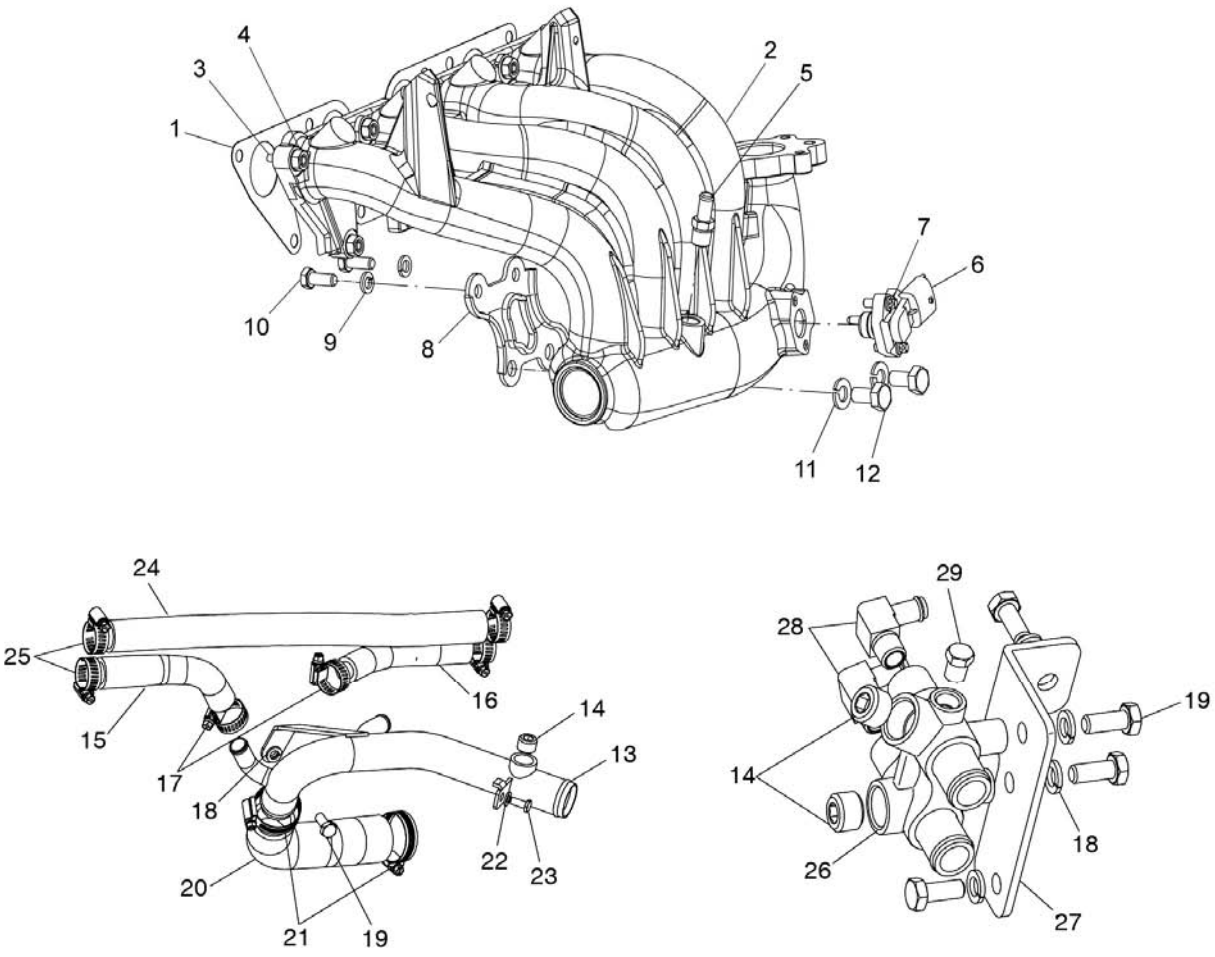
Engine Exploded View (2 of 2)



1) ENGINE
3) SPARK PLUG
4) ARM
5) SEAT
6) ADJUSTER
7) KEY
8) CAP
9) SPRING
10) SEAL
11) SEAT
12) GUIDE
28) STUD
29) NUT
31) MANIFOLD
32) GASKET
33) VALVE
34) SEAT
35) VALVE
36) SEAT
37) GASKET
38) HEAD
40) BOLT
49) STUD
66) PIN
67) HOUSING
69) WASHER
71) CAMSHAFT
72) PIN
73) STUD
74) CAP
75) SEAL
76) COVER
77) GASDET
78) BAFFLE
79) TUBE
80) BOLT
81) BRACKET
82) BRACKET
83) BRACKET
86) BOLT
87) BRACKET
88) COVER
89) SEAL
90) BOLT
91) RETAINER
92) RETAINER
93) RETAINER
94) RETAINER
95) WIRE
96) WIRE
97) WIRE
98) WIRE
99) WIRE KIT
100) STRAP
104) COIL
105) BOLT
107) GASKET
108) MANIFOLD
113) HOSE
115) COVER
116) BOLT
117) ADAPTER
118) BOLT
119) COVER
120) BOLT
121) SPROCKET
122) WASHER
123) BOLT
124) BELT
125) TENSIONER
126) BOLT
128) SPACER
129) KEY
130) SEAL
131) SPROCKET
132) WASHER
133) BOLT
134) SEAL
135) HOUSING
136) SENSOR
137) BOLT
140) SEAL
141) THERMOSTAT
142) BOLT
143) INJECTOR
144) SEAL
145) INJETOR
146) REGULATOR
148) SEAL
149) SEAL KIT
150) CLIP
151) BOLT
152) BOLT
153) COVER
154) GASKET
160) TUBE
161) TUBE
162) FITTING
164) BOLT
165) INLET
166) STUD
167) SEAL
168) VALVE
169) HOSE
170) CLAMP
171) CLAMP
172) HOSE
173) BALANCER
174) BOLT
175) PIPE
176) BOLT
177) TUBE
180) ADAPTER
181) WASHER
183) STUD
184) NUT

Intake manifold and gasket

Components



1) Gasket	2) Intake Manifold Assy	3) Stud Bolt	4) Nut	5) Fitting
6) Tmap	7) Bolt	8) Bracket-Stay	9) Washer	10) Bolt
11) Washer	12) Bolt	13) Pipe	14) Plug	15) Hose
16) Hose	17) Clamp	18) Washer	19) Bolt	20) Hose
21) Clamp	22) Washer	23) Bolt	24) Hose	25) Clamp
26) Block	27) Bracket	28) Fitting	29) Plug	

Removal

Remove or Disconnect

1. Relieve of fuel line pressure:

- Fuel-off solenoid valve disconnect.
- Run the engine and leave it running until stopping by lack of fuel.
- Run the engine for about 5 seconds so as to fully depressurize the fuel system.
- Fuel pump electric connection, from the tank upper area
- Run the engine and let it idle until it stops by lack of fuel.
- Start the engine for about 5 seconds, so as to obtain full pressure relief in the fuel system.

2. Disconnect the wiring harness from electronic components.

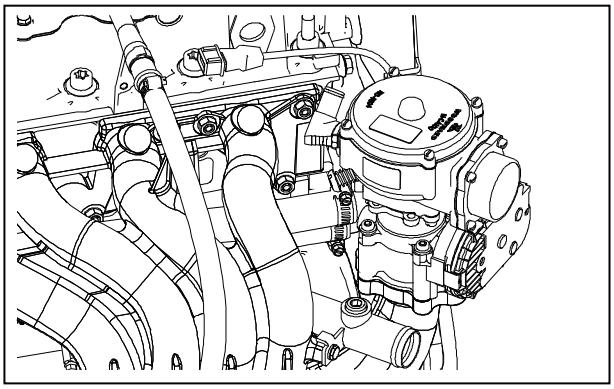
3. Battery negative cable.

4. Drain the coolant, releasing the radiator lower hose.

5. Disconnect the fitting of gasoline fuel hose from the fuel tank. (G424FE DF)

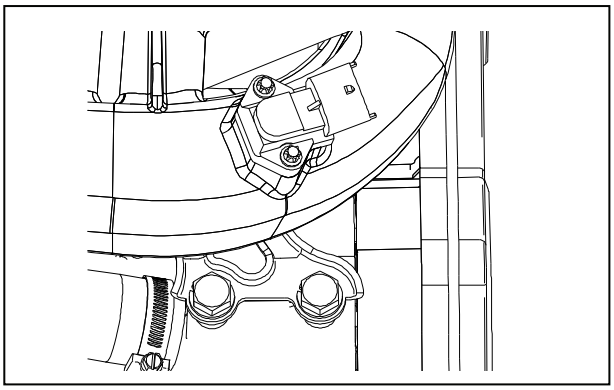
6. Disconnect the fuel hose and balance line, air hose.

7. Disconnect carburetor assembly by using 5mm hex-bit socket wrench handle.



8. Disconnect the PCV hose by using a screw driver.

9. Remove bracket attaching bolts by using 17mm spanner.

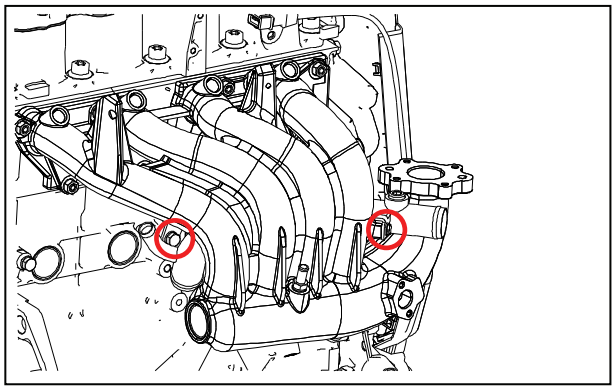


10. If necessary, remove the fuel rain from intake manifold by using 12mm socket wrench and extension.

11. If necessary, remove TMAP sensor attaching screws by using E-8 socket wrench with extension.

12. Remove all hose clamps and hose by using screw driver.

13. Remove coolant pipe attaching bolts by using 13mm spanner and 10mm socket wrench.



14. Remove manifold attaching bolts from the head by using 13mm wrench.

15. Remove the intake manifold.

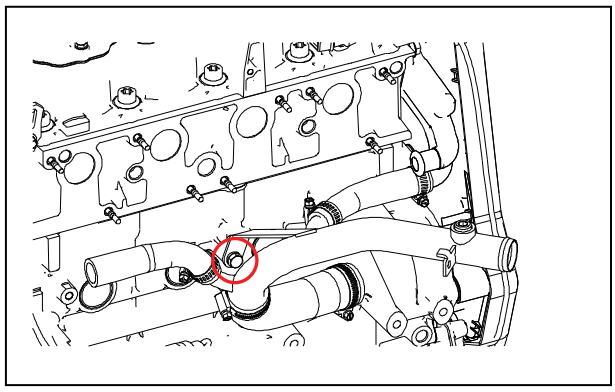
Clean

- Gasket residues from the intake manifold and cylinder head, taking care not to scratch the gasket mating surfaces.

Installation

Install or connect

1. Coolant pipe attaching bolt with cylinder block in its place.



2. With 13mm torque spanner, proper torque; tighten.
Tighten

- Bolts: 18 – 22 N·m (13 – 16 lb·ft.).

3. Hose clamp with torque driver; tighten.
Tighten

- Clamps: 1.5 – 2 N·m (1.1 – 1.5 lb·ft.).

4. A new gasket between intake manifold and cylinder head.

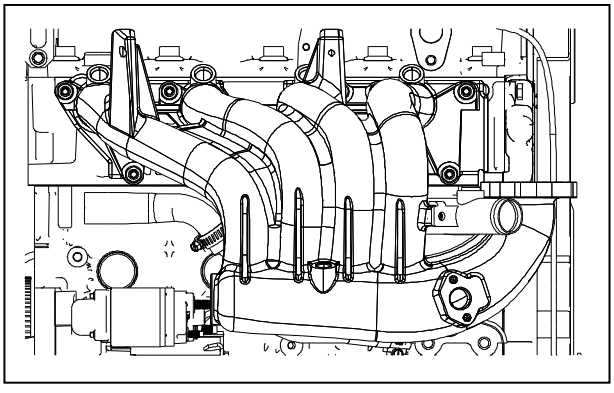
5. Intake manifold and its attaching nuts, without tightening.

6. With a 13-mm socket wrench, extension and proper torque wrench; tighten.

Tighten

- Nuts: 18 – 22 N·m (13 – 16 lb·ft.).

Obs.: Tighten the intake manifold nuts in a crisscross sequence, from the center to the ends.



7. Put the pipe on the manifold.

8. With a 10-mm socket wrench, extension and proper torque wrench; tighten.

Tighten

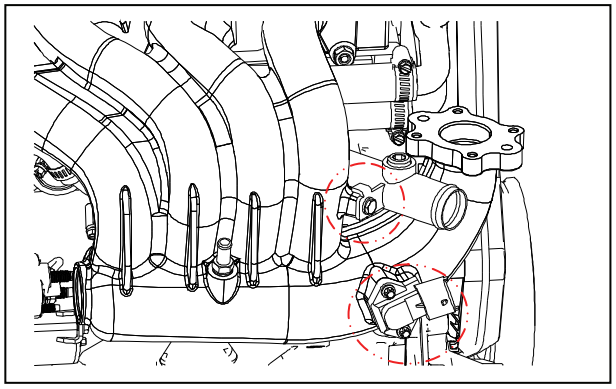
- Bolts: 5 – 6 N·m (3.7 – 4.4 lb·ft.).

9. Insert the TMAP onto manifold with greased o-ring.

10. With an E-8 socket wrench, extension and proper torque wrench; tighten.

Tighten

- Bolts: 6– 7 N·m (4.4 – 5.2 lb·ft.).



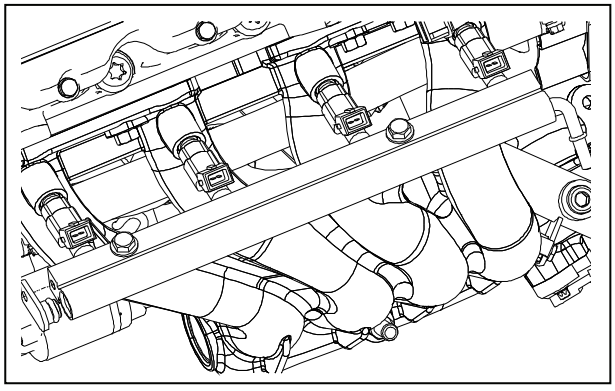
11. MAP sensor electric connector in the intake manifold rear area.

12. Insert the fuel rail with injectors in the hole of manifold and paste oil and grease to o-ring of injector. (G424FE)

13. With a 12-mm socket wrench, extension and proper torque wrench; tighten.

Tighten

- Nuts: 18 – 22 N·m (13 – 16 lb·ft.).



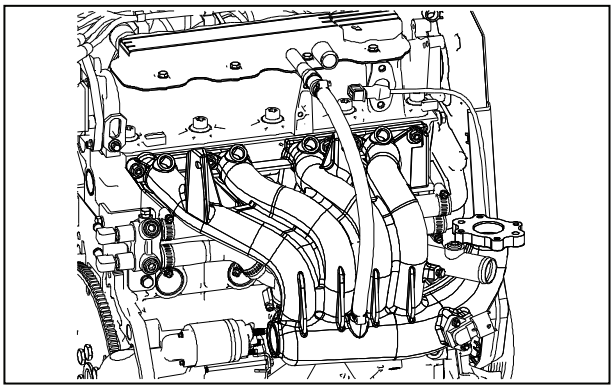
14. Connect wiring to the injectors.

15. Connect the PCV hose between PCV and fitting.

16. Hose clamp with torque driver; tighten.

Tighten

- Clamps: 1. – 1.5 N·m (0.75 – 1.1 lb·ft.).

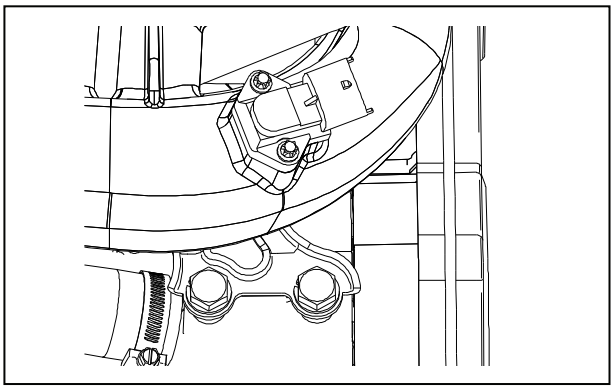


17. Bracket-stay and its attaching nuts, without tightening.

18. With a 17-mm torque spanner; tighten.

Tighten

- Nuts: 35– 40 N·m (25.8 – 29.5 lb·ft.).



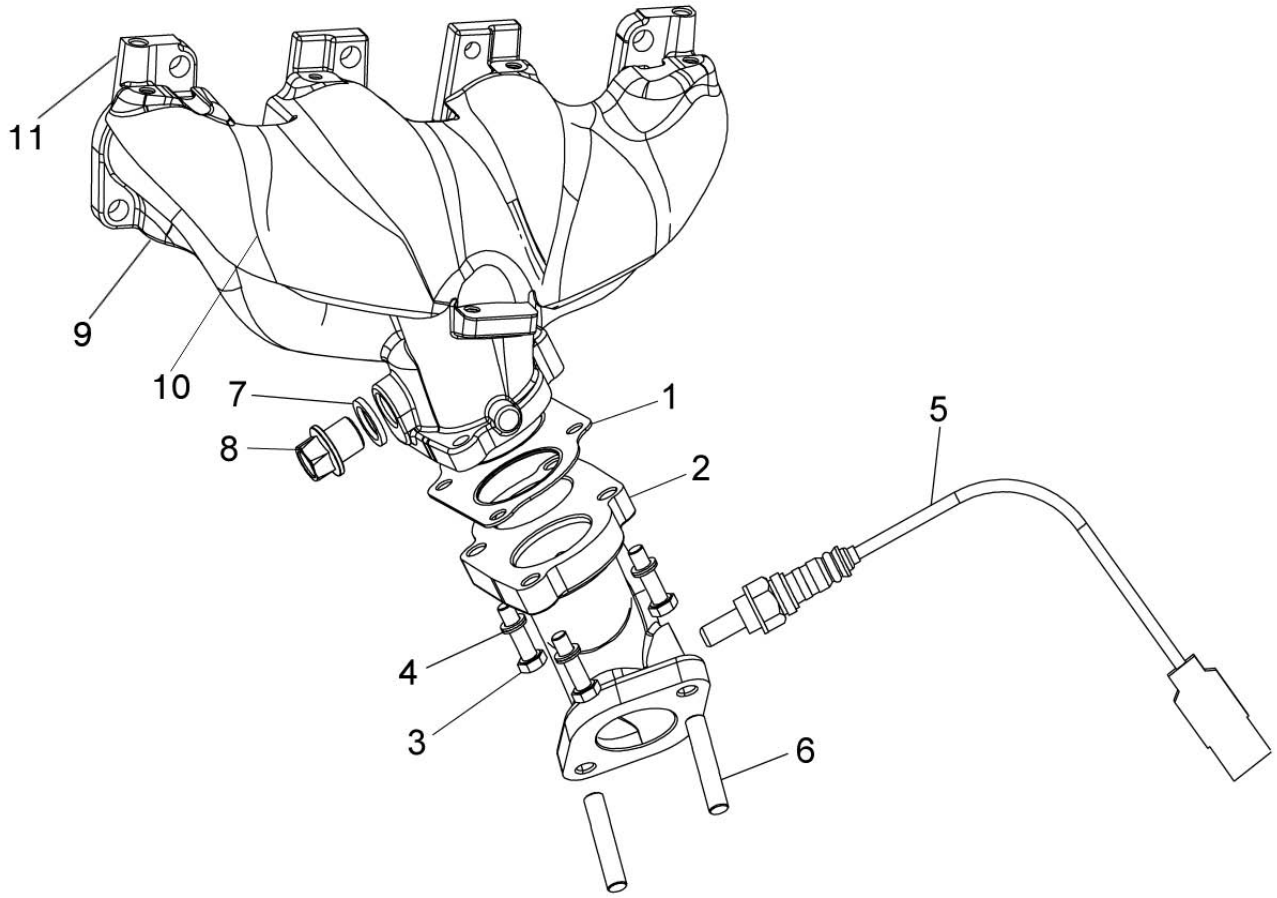
19. A new gasket between mixer assembly and intake manifold.

20. Mixer assembly and its attaching nuts, without tightening.

21. With a 5mm hex-bit socket wrench and torque wrench; tighten by using thread locker.

Exhaust Manifold and Gasket

Components



1) Gasket
2) Adapter-Exhaust Manifold
3) Bolt
4) Washer
5) O2 Sensor
6) Stud Bolt
7) Washer
8) Bolt
9) Exhaust Manifold
10) Shield
11) Gasket

Removal

Remove or disconnect

1. Spark plug cable terminals;

2. Exhaust manifold heat shield and remove dipstick tube (to allow removal of #3 plug wire).

3. Oxygen sensor (O2) electric connection.

4. Adapter-Manifold

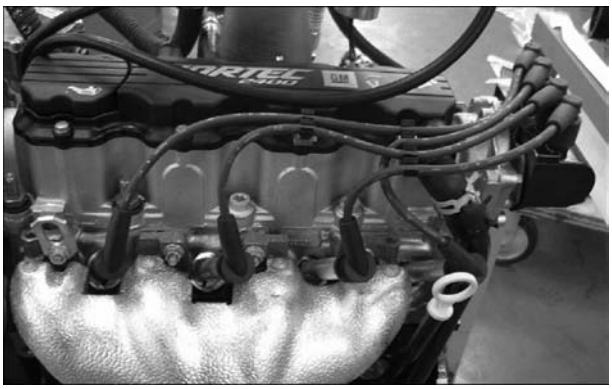
5. Remove attaching bolts of adapter with 6 mm hex – bit socket.

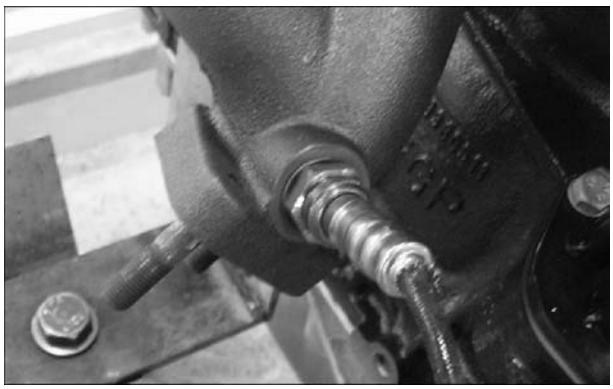
6. Exhaust manifold-to-cylinder head attaching nuts, with a 13-mm socket wrench, extension and handle.

7. Exhaust manifold and gasket.

Clean

- Exhaust manifold and cylinder head gasket residues, taking care not to scratch the gasket mating surfaces.





Installation

Install or connect

1. New gasket between the exhaust manifold and cylinder head.

2. Exhaust manifold and attaching nuts, without tightening.

3. With a 13-mm socket wrench, extension and torque wrench; tighten.

Tighten

- Nuts: 18 – 22 N·m (13 – 16 lb·ft.)

4. New gasket between the exhaust manifold and adapter.

5. Exhaust adapter and attaching bolts Without tightening.

6. With a 6mm hex-bit socket, extension and torque wrench; tighten.

- Tighten : 25 ~ 30N.m

7. Oxygen sensor to the adapter, with 22mm torque spanner tighten.

8. Washer and plug to the exhaust manifold, with 19mm socket wrench, extension and Torque wrench; tighten.

- Torque : 60 ~ 70N.m

9. Heat shield and attaching bolts, without tightening.

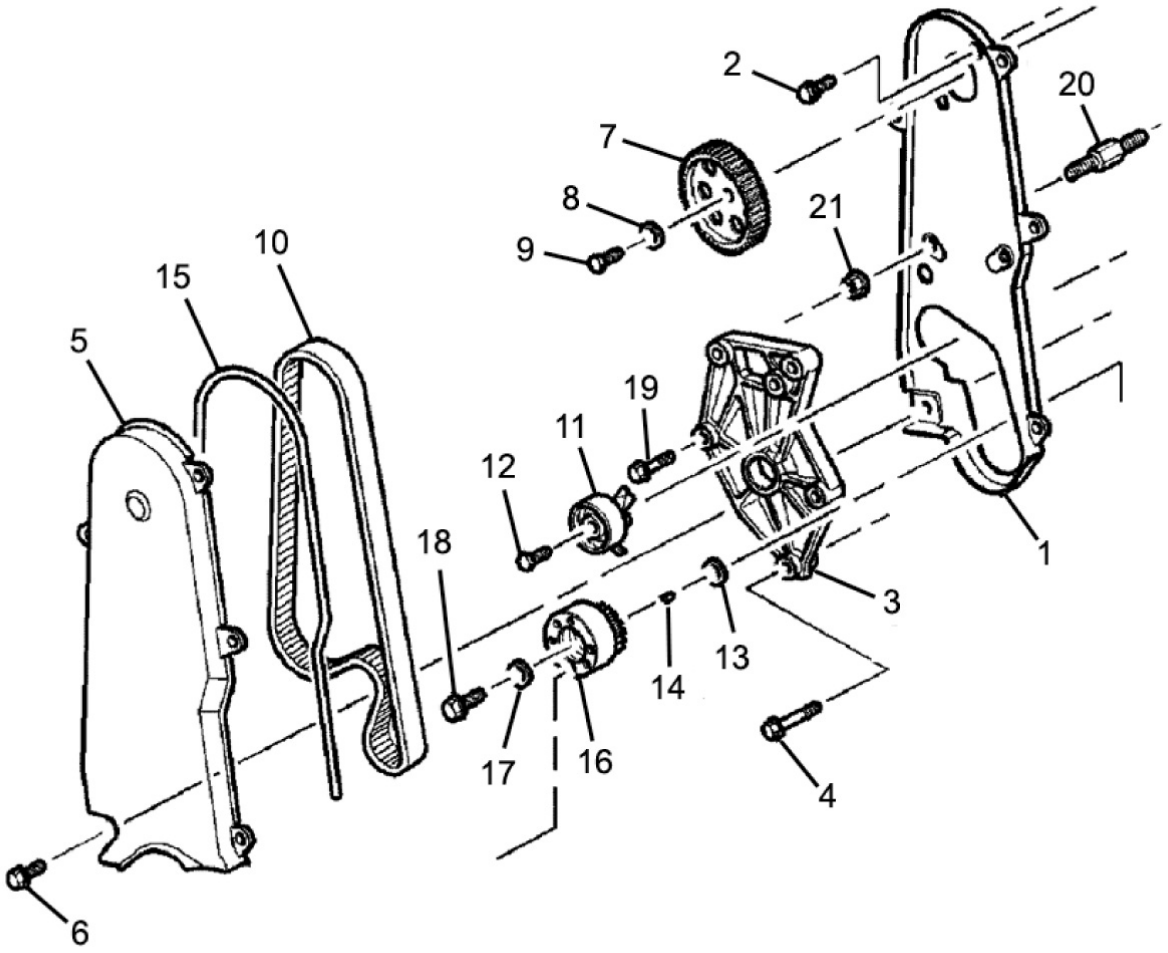
10. With a T30 socket wrench and torque Wrench; tighten.

- Tighten: 6 ~ 8N.m

11. Spark plug cables, observing their sequence.

Timing Belt

Components



1) Cover
2) Bolt
3) Adapter
4) Bolt
5) Cover
6) Bolt
7) Sprocket
8) Washer
9) Bolt
10) Belt-timing
11) Tensioner-Timing Belt
12) Bolt
13) Spacer
14) Key
15) Seal
16) Sprocket
17) Washer
18) Bolt
19) Bolt
20) Stud
21) Nut

Removal

Remove or disconnect

1. Crankshaft pulley; see “Crankshaft Pulley – Removal”, in this section.

2. V pulley belt automatic Tensioner; see “V Pulley Belt Automatic Tensioner – Removal”, in this section.

3. Timing belt front cover attaching bolt, with an E10 Torx socket wrench, extension and handle

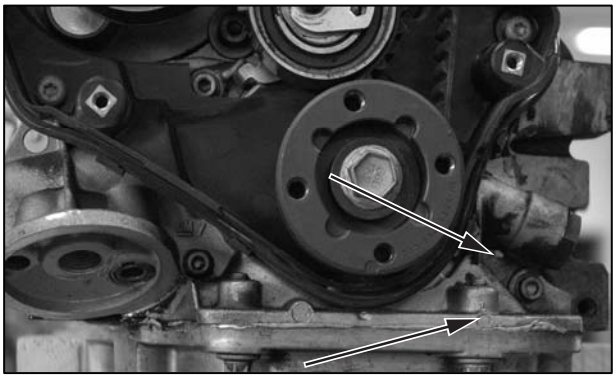
4. Timing belt front cover.

Important

- Note the camshaft pulley alignment with the timing mark on the timing belt cover.
- Turn the crankshaft until aligning the timing pulley mark with the oil pump case flange, in the no. 1 cylinder combustion stroke.

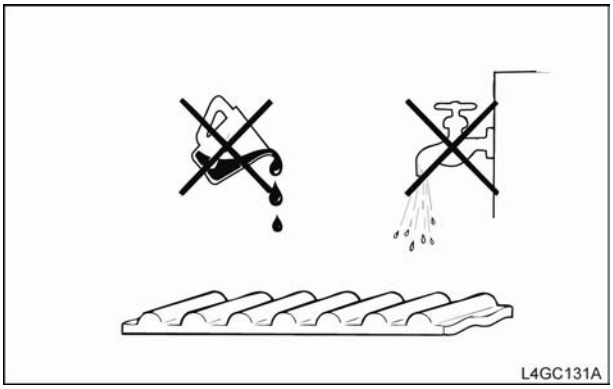
5. Loosen the timing belt Tensioner bolt with a 13-mm combination wrench, releasing belt tension.

6. Timing belt, marking the running direction/front edge of the belt in case of using the same belt.



Timing Belt

Inspection

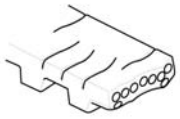
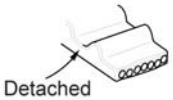
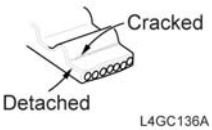
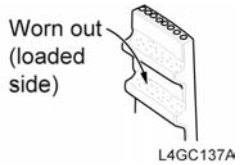
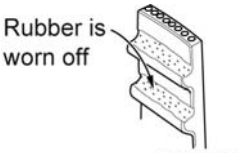
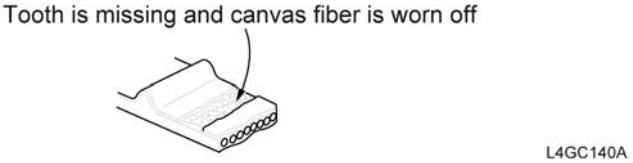
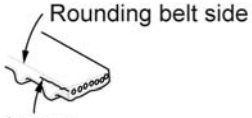
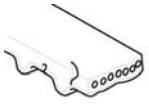


1. Check the belt for oil or dust deposit and replace it if necessary. In case of small amount of oil or dust, clean it with a rag or paper instead of a solvent.

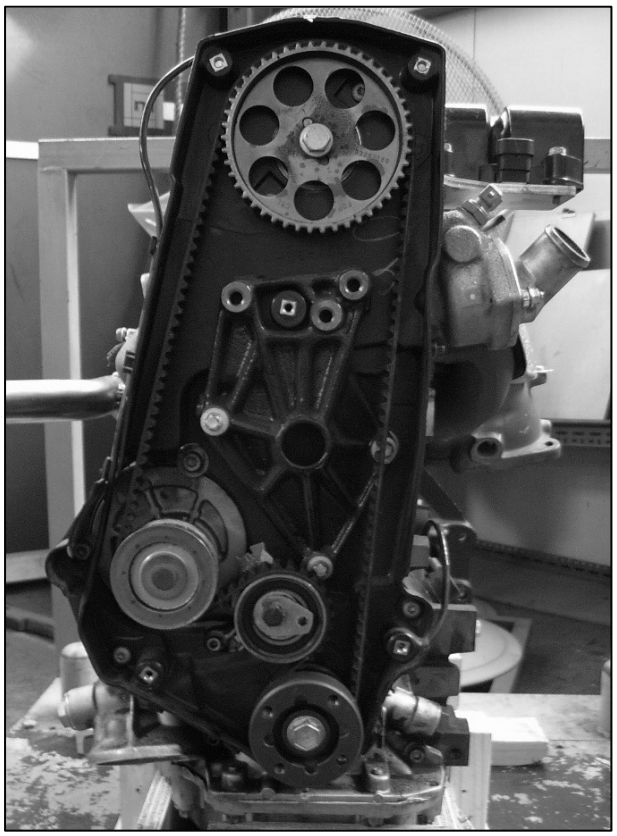
2. After overhauling the engine or readjusting the belt, inspect the belt in detail and replace it with a new one if the following defects are detected.

⚠ CAUTION

Do not bend or twist the timing belt.
Take care not to contact the timing belt with oil, water, grease and steam.

Description	Specification
1. Back side rubber is hardened	Glossy back side. Due to non-elasticity and hardening, when pressing it with the tip of a finger, there is no sign of it.  L4GC132A
2. Back side rubber is cracked	 L4GC133A
3. Canvas is cracked or detached	 L4GC134A  L4GC135A  L4GC136A
4. Tooth is excessively worn out (initial step)	Tooth loaded from canvas is worn (elastic canvas fiber rubber is worn, color is faded in white, canvas structure is deformed)  L4GC137A
5. Tooth is excessively worn out (final step)	Tooth loaded from canvas is Worn and rubber is worn off (tooth width is narrowed)  L4GC138A
6. Tooth bottom is cracked	 L4GC139A
7. Tooth is missing	 L4GC140A
8. The side of belt is severely worn out	 L4GC141A
9. The side of belt is cracked	**NOTE: In case of normal belt, it is cut precisely as if cut with a sharp cutter**  L4GC142A

Installation



Install or connect

Important

- Align the camshaft timing pulley mark with the timing belt rear cover mark.
- Align the crankshaft timing pulley mark with the oil pump case flange, in the no. 1 cylinder combustion stroke.

1. Timing belt

2. Belt Tensioner adjustment: with a 6-mm Allen wrench, so as to keep steady the Tensioner shaft, loosen the Tensioner shaft attaching bolt until the same becomes steady.
With a 6-mm Allen wrench, turn clockwise the Tensioner installation shaft up to the “NEW” marking point (± mm) (Detail B). The needle may move from the right side up to the final adjusting position. Tighten the bolt. For used timing belts, follow the same procedure, but with the belt adjustment in the “USED” position.
This change is suggested due to the used belt presenting a different course of action regarding the new belt.

3. Timing belt front cover.

4. Timing belt front cover attaching bolts, with a 10-mm socket wrench and handle.

5. V pulley belt automatic Tensioner; see “V Pulley Belt Automatic Tensioner – Installation”, in this Section.

6. Crankshaft pulley; see “Crankshaft Pulley – Installation”, in this section.

Timing Belt Tensioner

Removal

Remove or disconnect

1. Timing belt; see instructions under “Timing Belt – Removal”, in this section.

2. Timing belt Tensioner bolt, in the oil pump case, with a 13-mm socket wrench and handle.

3. Timing belt Tensioner.

Install or connect

1. Tensioner in the oil pump case.

Important

- The lug (1) in the Tensioner base should be lodged in the hole (2) of the oil pump case.

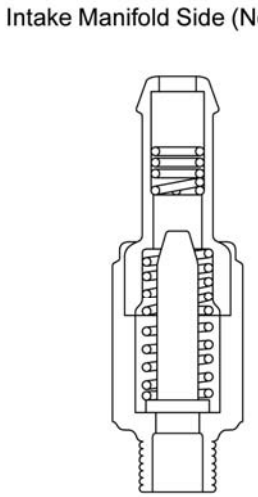
2. Tensioner attaching bolt, without tightening.

3. Timing belt; see “Timing Belt – Installation”, in this section.

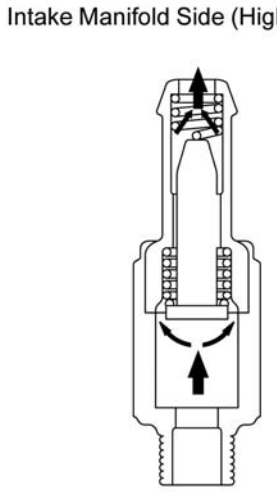


PCV Valve

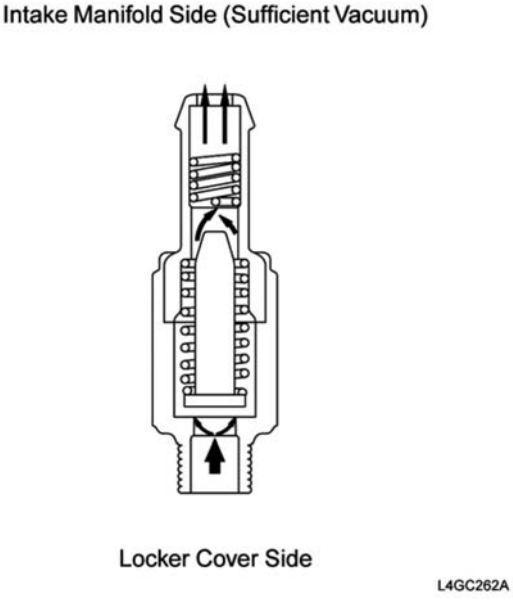
Outline and Operation Principle



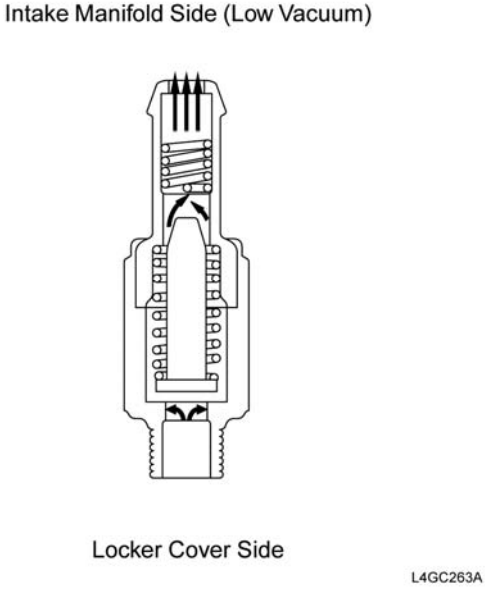
Engine condition	No operating
PCV valve	No operating
Vacuum path	Clogged



Engine condition	At idle or deceleration
PCV valve	Full operating
Vacuum path	Small

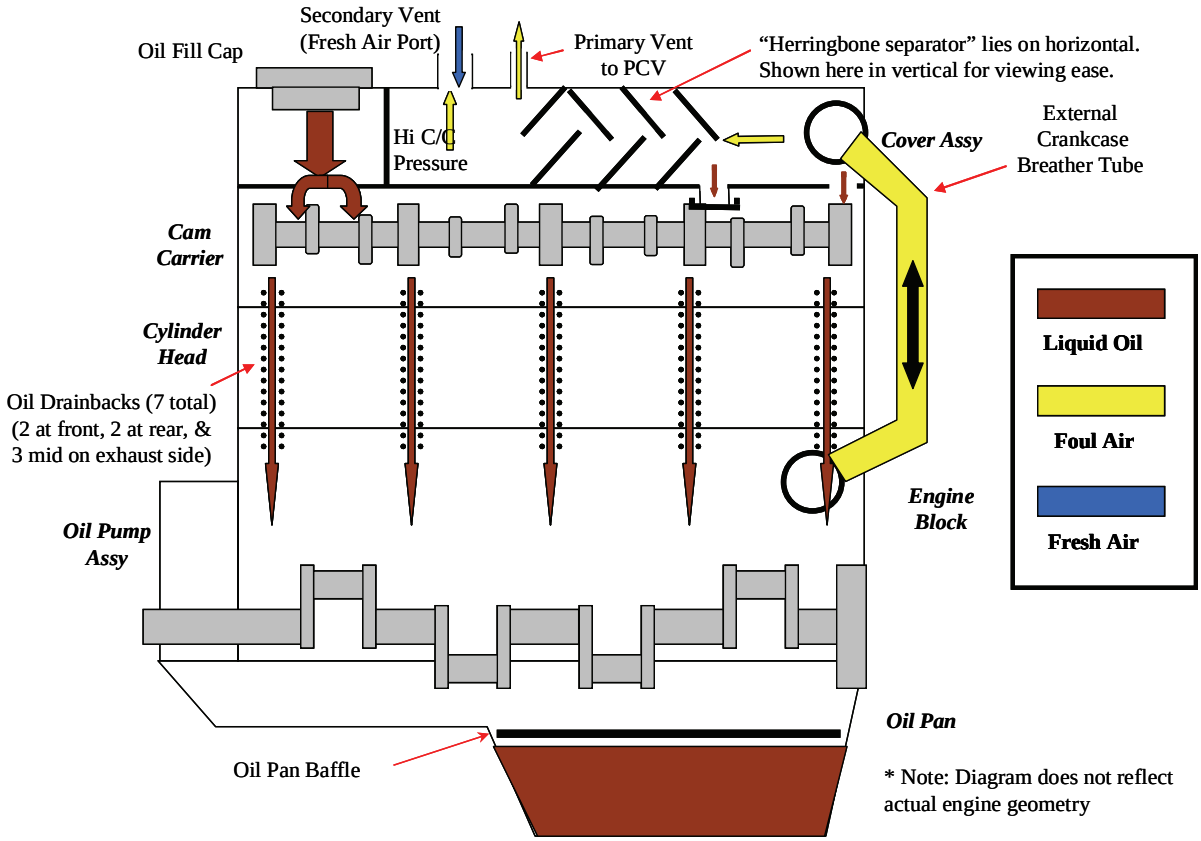


Engine condition	Proper operating
PCV valve	Proper operating
Vacuum path	Big



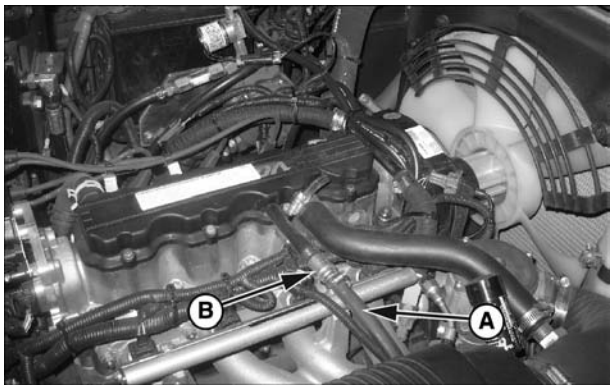
Engine condition	High speed and overload
PCV valve	Light operating
Vacuum path	Very big

Crankcase Ventilation

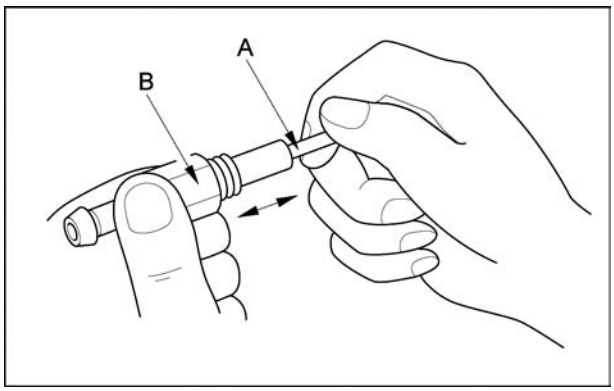


Service Procedure

REMOVAL



1. After disconnecting the vacuum hose (A), remove the PCV valve (B).



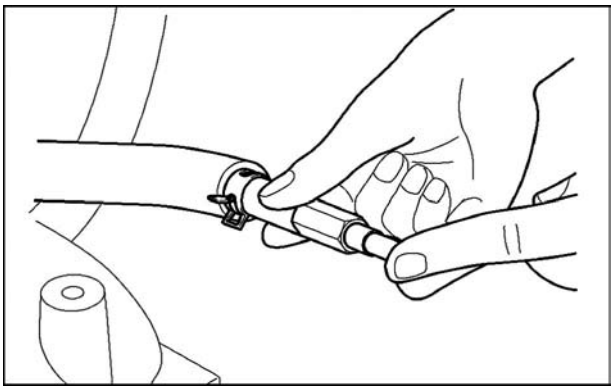
INSPECTION

1. Remove the PCV valve.

2. Check the plunger for movement by inserting a thin stick (A) toward the valve (B) nut.

3. If the plunger is not moved, it means that PCV valve is clogging, so, clean or replace PCV valve.

TROUBLESHOOTING



1. Disconnect the vacuum hose from the PCV valve.

2. With the engine at idle, Check the intake manifold for vacuum when clogging the opened end of PCV valve.

NOTE: The plunger in PCV valve will move back and forth.

3. If vacuum is not detected, clean or replace PCV valve and vacuum hose.

INSTALLATION

Install the PCV valve and connect the vacuum hose.

Camshaft Timing Pulley and/or Seal

Removal

Remove or disconnect

1. Timing belt; see “Timing Belt – Removal”, in this section.

2. Camshaft case cover; see “Camshaft Case Cover – Removal”, in this section.

3. Camshaft timing pulley attaching bolt, holding the camshaft with a 22-mm wrench and use a 17-mm combination wrench to loosen the camshaft timing pulley attaching bolt.

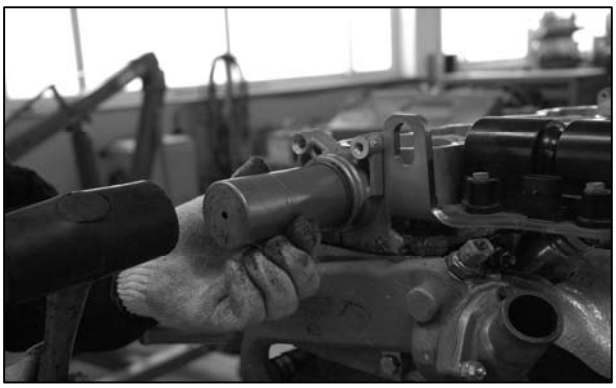
Important

- Mark the orientation of the camshaft timing pulley before removal.

4. Camshaft timing pulley.

5. Camshaft seal; for this operation, drill a hole in the seal front face and install a fine thread bolt. With the aid of pliers, pull the seal.





Installation

Install or connect

1. New seal in the camshaft case, with the aid of tool KM-422, camshaft pulley washer and bolt.

2. Camshaft timing pulley and its bolt, with a 22-mm wrench, to lock the camshaft and a 17-mm socket wrench and torque wrench; tighten.

Tighten

- Bolt: 40 – 50 N·m (30 – 37 lb·ft.).

3. Camshaft case cover; see “Camshaft Case Cover – Installation”, in this Section.

4. Timing belt; see “Timing Belt – Installation”, in this section.

Crankshaft Timing Pulley

Removal

Remove or disconnect

1. V pulley belt; see “V Pulley Belt – Removal”, in this section.

2. Timing pulley attaching bolt, with a 13-mm socket.

3. Timing pulley; if it is locked, use tool 6-8604028 to remove the same.

4. Timing pulley key.

Installation

Install or connect

1. Key in the timing pulley.

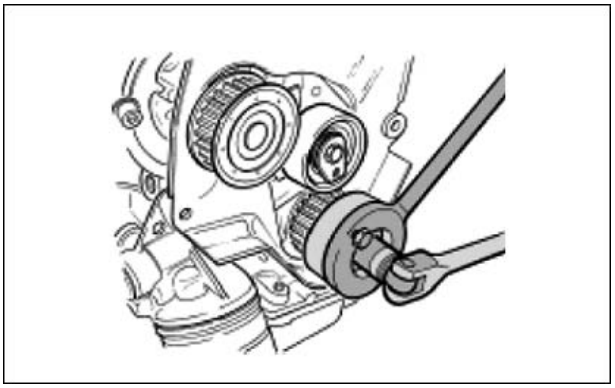
2. Timing pulley and attaching bolt, without tightening.

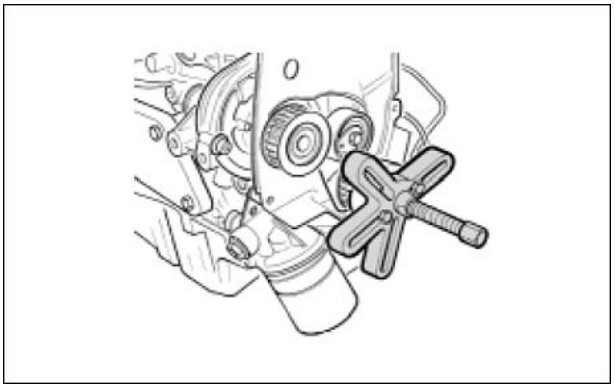
3. Use a 13-mm socket wrench; tighten.

Tighten

- Bolt: 135 + 30° + 15° (99 lb·ft. + 30° + 15°).

4. V pulley belt; see “V Pulley Belt – Installation”, in this section.





Crankshaft Front Seal

Removal

Remove or disconnect

1. Timing belt; see “Timing Belt – Removal”, in this section.

2. Crankshaft timing pulley; see “Crankshaft Timing Pulley – Removal”, in this section.

3. Crankshaft seal. For this operation, drill a hole in the seal front face and install a fine threaded bolt (arrow).
With the aid of pliers, remove the seal.

Installation

Install or connect

1. New seal to the crankshaft.

Important

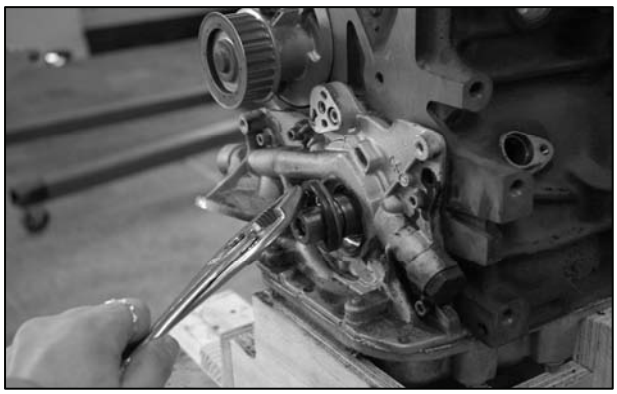
- Install tool KM-417 protecting sleeve on the crankshaft end with its outer surface lubricated and the chamfered area turned to the outside of the vehicle.
- Install the seal in the protecting sleeve.
- Place installer KM-417 and bolt and install the seal in its lodging.

2. Remove tool and protecting sleeve.

3. Timing pulley in the crankshaft; see “Crankshaft Timing Pulley – Installation”, in this section.

4. Timing belt; see “Timing Belt – Installation”, in this section.







Camshaft Case Cover and Gasket

Removal

Remove or disconnect

1. Spark plug cables from the support.

2. Breather hose from the valve cover.

3. Camshaft case cover attaching bolts, with a 10-mm socket wrench and handle.

4. Camshaft case cover and gasket.

Installation

Install or connect

1. A new gasket and camshaft case cover.

2. Camshaft cover attaching bolts, without tightening.

Obs.: Install the spark plug cables together with the bolts.

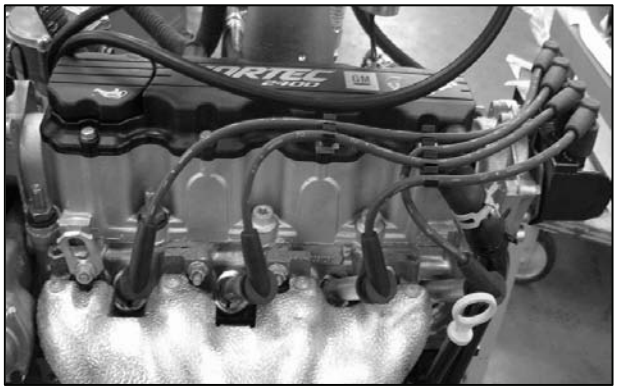
3. With a 10-mm socket wrench, extension and torque wrench; tighten.

Tighten

- Bolts: 4 – 10 N·m (3 – 7 lb·ft.).

4. Breather hoses in the camshaft case cover.

5. Spark plug cables on the supports.



Crankshaft Accessory Pulley

Removal

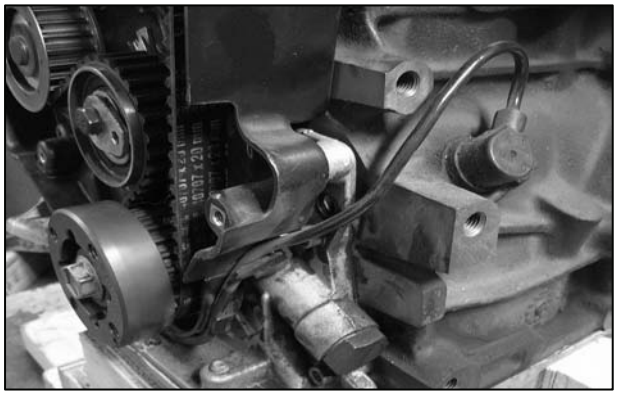
Remove or disconnect

1. V pulley belt; see “V Pulley Belt – Removal”, in this section.

2. Crankshaft accessory pulley attaching bolt, with a 13-mm socket wrench and handle.

3. Crankshaft pulley.

4. TDC sensor and CAS sensor.



Installation

Install or connect

1. Accessory pulley with attaching bolts, without tightening.
2. With a 13-mm socket wrench and torque wrench; tighten the pulley attaching bolts.

Tighten

- Bolts: 15 – 25 N·m (11 – 18 lb·ft.).

3. V pulley belt; see “V Pulley Belt – Installation”, in this section.

Timing Belt Rear Cover

Removal

Remove or disconnect

1. Timing belt; See “Timing Belt – Removal”, in this section.

2. Camshaft timing pulley; see “Camshaft Timing Pulley – Removal”, in this section.

3. Crankshaft timing pulley; see “Crankshaft Timing Pulley – Removal”, in this section.

4. Timing belt rear cover attaching bolts and nuts, with a T30 Torx socket wrench; extension and handle.

5. Timing belt rear cover.

Installation

Install or connect

1. Timing belt rear cover and attaching bolts and nuts, without tightening.

2. With a T30 Torx wrench, and extension; tighten.

Tighten

- Bolts: 5 – 10 N·m (4 – 7 lb·ft.).
- Nuts: 5 – 10 N·m (4 – 7 lb·ft.).

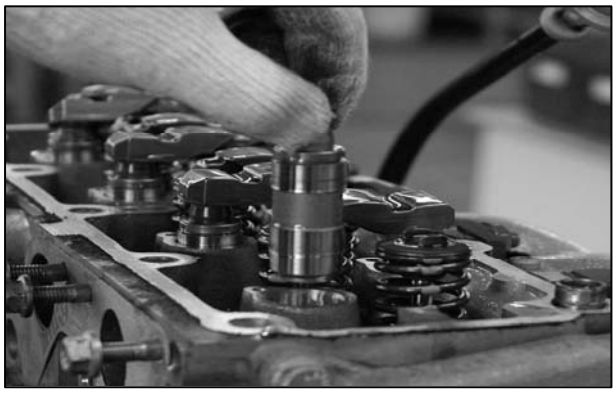
3. Crankshaft timing pulley; see “Crankshaft Timing Pulley – Installation”, in this section.

4. Camshaft timing pulley; see “Camshaft Timing Pulley – Installation”, in this section.

5. Timing belt; see “Timing Belt – Installation”, in this section.

Rocker Arms, Linkage, Valve Lifters With Cylinder Head and Engine





Removal

Remove or disconnect

1. Camshaft case cover; see “Camshaft Cover – Removal”, in this section.

2. Attach tool KM-565-A in the camshaft case, supporting it over the spring plate corresponding to the rocker arm to be removed.

3. Drive the tool pressing the valve spring.

4. Rocker arm, linkage.

5. Valve lifter.

Installation

Install or connect

1. Valve lifter, linkage and rocker arm.

2. Release the valve spring.

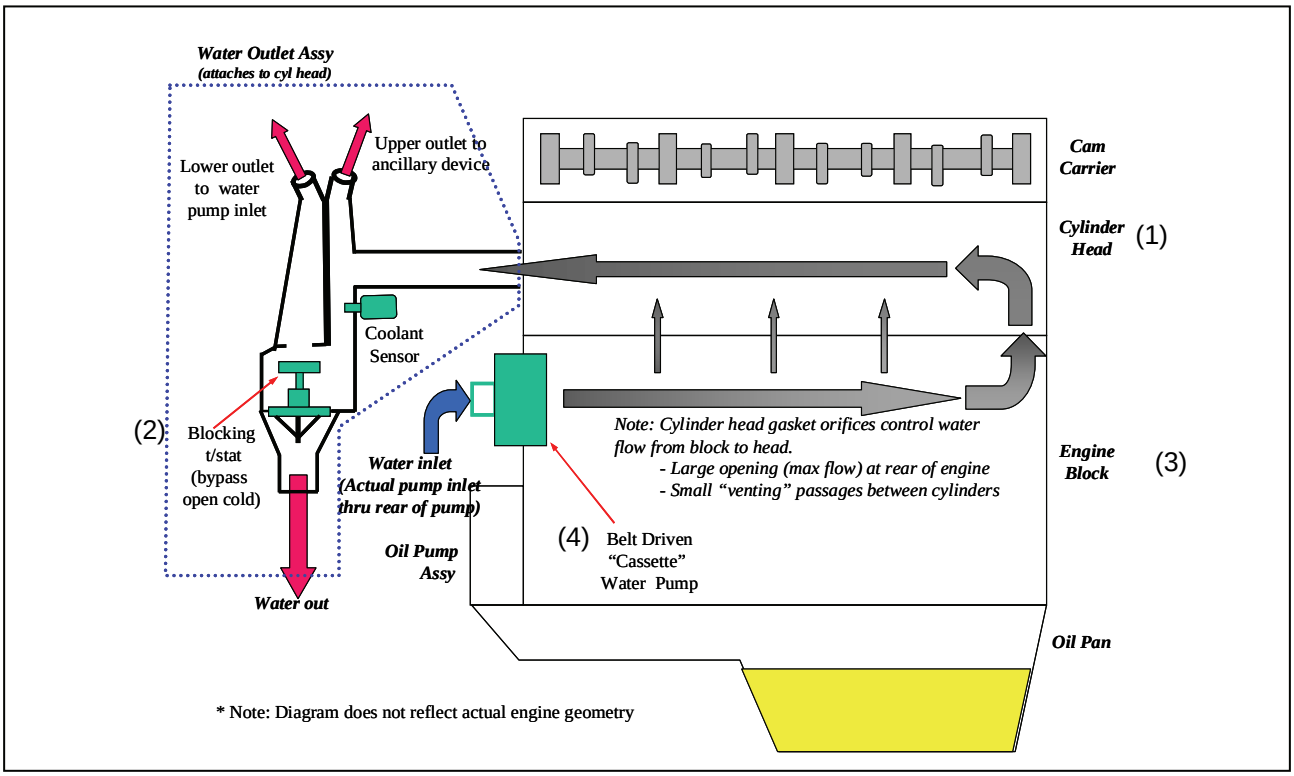
3. Remove tool KM-565-A.

4. Camshaft case cover; see “Camshaft Case Cover - Installation”, in this section.



Cooling System

General Description


Water Outlet Assy
(attaches to cyl head)
Lower outlet to water pump inlet
Upper outlet to ancillary device
Cam Carrier
Cylinder Head
(1)
Coolant Sensor
(2)
Blocking t/stat (bypass open cold)
Water inlet
(Actual pump inlet thru rear of pump)
Note: Cylinder head gasket orifices control water flow from block to head.
- Large opening (max flow) at rear of engine
- Small "venting" passages between cylinders
Engine Block
(3)
Oil Pump Assy
(4)
Belt Driven "Cassette" Water Pump
Water out
Oil Pan
* Note: Diagram does not reflect actual engine geometry

Cooling System Schematic

1) Cylinder head. 2) Thermostat. 3) Cylinder walls. 4) Water pump.

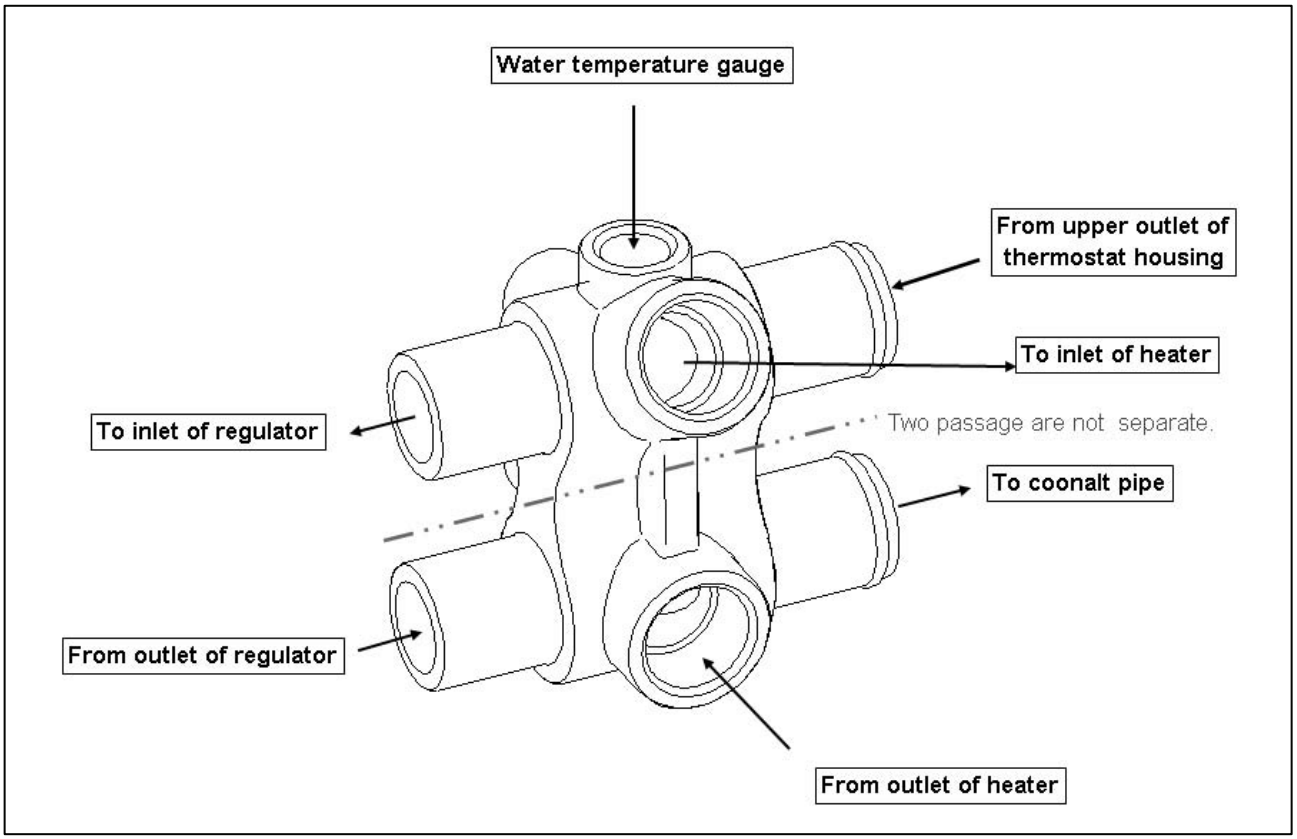
Water pump (4) is installed on the front of the cylinder block. The water pump is driven by timing bolt.The inlet opening of the water pump is connected to the radiator lower hose. The outlet flow from the water pump goes through passages inside the cylinder block.

The coolant from the water pump through the cylinder block passages has primary coolant flow to and around the seats for the exhaust valves. This method gives the coolant with the coolest temperature flow to the hottest area during engine operation.

Cylinder walls (3) are cooled by the coolant flow through the block. After the coolant goes through the cylinder block it flows through cylinder head (1) to the thermostat housing, where the bypass type thermostat (2) is installed. The thermostat controls the opening to radiator to control the temperature in the cooling system.

If the coolant is cold (cool), the thermostat will be closed. The coolant circulates (makes a complete circuit) from the water pump and through the cylinder block until the temperature of the coolant is warm enough to make the thermostat open. When thermostat (2) is open the coolant will go through radiator top hose and into the top tank of radiator. Coolant then goes through the cores of the radiator. The air from the fan will make the coolant cool as the coolant flows to the bottom of the radiator and out hose where the coolant returns to water pump. The radiator is equipped with a shroud to increase the efficiency of the fan and cause the air to be pushed through the radiator and away from the lift truck.

If the coolant is hot and the cooling system pressure is too high, some coolant flows to the top of radiator through the tube to recovery tank. The cooling system pressure is controlled by cap. When the cooling system pressure goes above its rated pressure, a valve opens in pressure cap which releases the cooling system pressure to the atmosphere. After the engine is at normal temperature for operation, a development of vacuum is present in the cooling system. Pressure cap permits air in the radiator to remove the vacuum at the same time coolant from recovery tank is pulled back into the radiator.


Water temperature gauge
From upper outlet of thermostat housing
To inlet of heater
To inlet of regulator
Two passage are not separate.
To coonalt pipe
From outlet of regulator
From outlet of heater

The thermostat housing has two outlet ports. Upper outlet port is connected to distribution block and lower outlet is connected to coolant pipe and coolant flow is recirculated to water inlet through coolant pipe until thermostat is open. The distribution block has 5 ports as shown a picture.

Testing and Adjusting

Adhere to the following warnings when performing any tests or adjustments while the engine is running:

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

⚠ WARNING

Exhaust fumes contain carbon monoxide (CO) which can cause personal injury or death. Start and operate the engine in a well ventilated area only. In an enclosed area, vent the exhaust to the outside.

This engine has a pressure type cooling system. A pressure type cooling system gives two advantages. The first advantage is that the cooling system can have safe operation at a temperature that is higher than the normal boiling (steam) point of water. The second advantage is that this type system prevents cavitation (the sudden making of low pressure bubbles in liquids by mechanical forces) in the water pump. With this type system, it is more difficult for an air or steam pocket to be made in the cooling system.

The cause for an engine getting too hot is generally because regular inspections of the cooling system were not made. Make a visual inspection of the cooling system before testing with testing equipment.

Cooling System Visual Inspection

⚠ WARNING

Do not loosen the filler cap or pressure cap on a hot engine. Steam or hot coolant can cause severe burns.

1. After the engine is cool, loosen the filler cap (on a radiator with a pressure cap, turn it to the first stop) to let pressure out of the cooling system. Then remove filler or pressure cap.

2. Check coolant level in the cooling system.

3. Look for leaks in the system.

4. Look for bent radiator fins. Be sure that air flow through the radiator does not have a restriction.

5. Inspect the drive belts for the fan.

6. Check for damage to the fan blades.

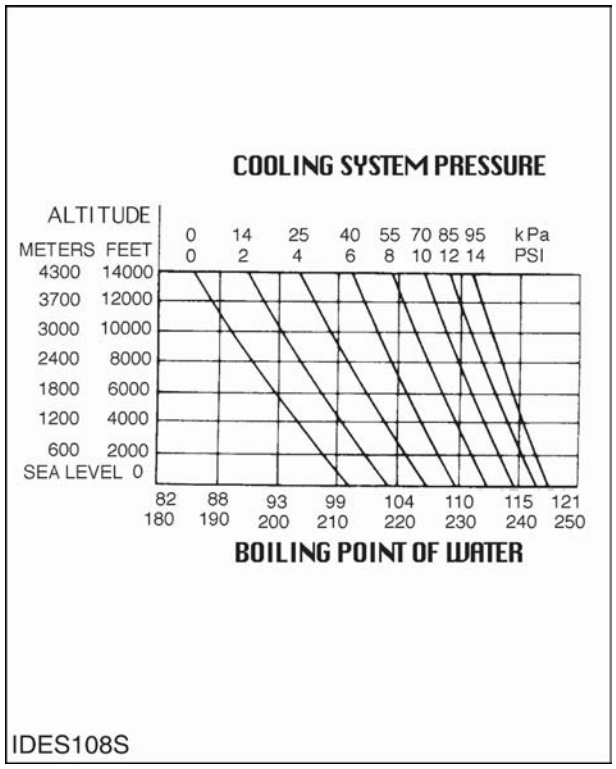
7. Look for air or combustion gas in the cooling system.

8. Inspect the filler cap and the surface that seals the cap. This surface must be clean.

9. Look for a large amount of dirt in the radiator core and on the engine.

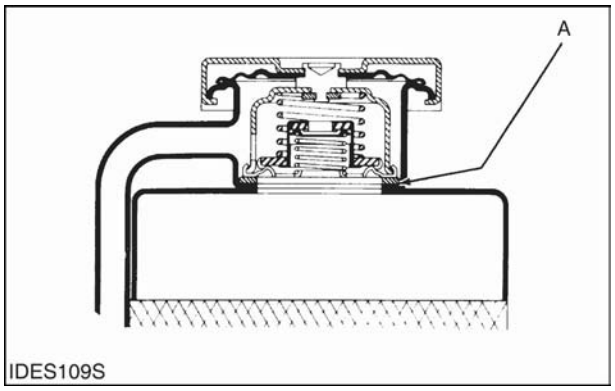
10. Check for loose or missing fan shrouds that cause poor flow of cooling air.

Cooling System Tests



Remember that temperature and pressure work together. When making a diagnosis of a cooling system problem, temperature and pressure must both be checked. Cooling system pressure will have an effect on cooling system temperatures. For an example, look at the chart to see the effect of pressure and height above sea level on the boiling (steam) point of water.

Pressure Cap Test



Pressure Cap Diagram
(A) Sealing surface of cap and radiator.

One cause for a pressure loss in the cooling system can be a bad seal on the pressure cap of the system. Inspect the pressure cap carefully. Look for damage to the seal or the sealing surface. Any foreign material or deposits on the cap, seal or seal or sealing surface must be removed.

To check the pressure cap opening pressure, do the following procedure.

⚠ WARNING

If the engine has been in operation and the coolant is hot, slowly loosen the pressure cap to the first stop and let the pressure out of the cooling system, then remove the pressure cap.

1. Remove pressure cap from the radiator.

2. Put the pressure cap on the Cooling System Pressurizing Pump Tool.

3. Look at the gauge for the pressure that makes the pressure cap open. It must be as follows:
A403658……76 to 100 kPa (11 to 14.5 psi)

4. If the pressure cap is bad, install a new pressure cap.

Cooling System Leak Check

To test the cooling system for leaks, use the following procedure:

⚠ WARNING

If the engine has been in operation and the coolant is hot, slowly loosen the pressure cap to the first stop and let the pressure out of the cooling system, then remove the pressure cap.

1. Remove pressure cap from the radiator.

2. Make sure the radiator is full (hot) or nearly full (cold) of coolant.

3. Attach the Cooling System Pressurizing Pump Tool to the radiator filler neck.

4. Pump the pressure to 20 kPa (3 psi) more than the rated pressure of the cap.

5. Check the radiator for outside leakage.

6. Check all connections and hoses of the cooling system for outside leakage.

7. If there is no outside leakage and the pressure reading on the gauge is still the same after 5 minutes, the radiator and cooling system do not have leakage. If the reading on the gauge goes down and there is no outside leakage, there is leakage on the inside of the cooling system. Make repairs as necessary

Thermostat

The thermostat is the wax pellet type. A jiggle valve (which improves air bleeding during water supply) is provided on the flange part. When the thermostat is closed, the circulation of coolant is stopped, thereby making warm-up faster.

Operation

When the temperature of the coolant is low, the valve is closed by the spring, with the result that the coolant circulates within the engine, without passing through the radiator.
When the temperature of the coolant rises and reaches a certain specified temperature, the valve opens and the coolant also circulates through the radiator.

When the temperature increases further and reaches a certain specified temperature, the valve opens fully, allowing even more coolant to circulate through the radiator.

Thus, in this way the degree of valve opening is varied according to the temperature of the coolant, and the temperature of the coolant is adjusted by varying the amount of coolant caused to circulate through the radiator.

Thermostat Test

To test the thermostat opening temperature, use the following procedure:

⚠ WARNING

The pan, water and thermostat will be very hot and can cause burns. Do not touch the pan, water or thermostat. Handle the components with an insulated device for protection.

1. Remove the thermostat from the engine.

2. Hang the thermostat in a pan of water. Put a thermometer in the water. Put the thermostat completely under water. Do not let the thermostat make contact with the pan.

3. Put heat to the pan of water. Make the water in the pan move around. This keeps all of the water at the same temperature.

4. The thermostat must start to open when the temperature is 82°C (180°F). The thermostat must be fully open at 96°C (205°F).

Cooling System Heat Problems

To check if there is a good reason for heat problems do the checks that follow:

1. The indications of a heat problem are as follows:

a. High coolant temperature indicator light is on or needle of coolant temperature gauge is in red range.

b. Coolant boils out (comes out because of too much heat) of the cooling system during operations.

c. Coolant boils out on the floor when the engine is stopped.

d. Coolant must be added at the end of each shift but Steps b and c are not present.

2. If indication in Step 1 a is only present. It is possible the problem is only a damaged gauge, light or sender. Make a replacement of the defective part.

3. If indication in Step 1b is present, do the procedure that follows:

a. Run the engine at medium idle (1200 rpm) for three minutes after high idle operation. This cools off the hottest parts of the engine before it is stopped.

b. Install a coolant recovery system on the truck, if not already equipped.

4. If indications in Step 1b, 1c or 1d are present, but Step 1a is not and the high temperature indicator light does work, the problem can be a damaged radiator cap seal or there can be a leak in the cooling system. Complete the procedure that follows:

a. Do the Pressure Cap Test, Cooling System Leak Check, Thermostat Test and Belt Adjustment in the Testing And Adjusting.

b. Clean the radiator with hot water (steam clean) at low pressure and use detergent or air according to the different types of debris that caused the radiator to be dirty (plugged).

c. Check the engine high idle setting.

NOTE: Another condition that can cause heat problems is the ignition timing. Retarded (late) timing causes the engine to send more heat to the cooling system. Advanced (early) timing causes the engine to send less heat to the cooling system.

Cooling System Recommendation

Coolant Information

The engine cooling system is provided with a mixture of 50% ethylene glycol anti-freeze and 50% water (For the vehicles of tropical area, the engine cooling system is provided with a mixture of 40% ethylene glycol anti-freeze and 60% water at the time of manufacture.)
Since the cylinder head and water pump body are made of aluminum alloy casting, be sure to use a 30 to 60% ethylene glycol antifreeze coolant to assure corrosion protection and freezing prevention.

⚠ WARNING

If the concentration of the antifreeze is below 30%, the anticorrosion property will be adversely affected. In addition, if the concentration is above 60%, both the antifreeze and engine cooling properties will decrease, adversely affecting the engine. For these reasons, be sure to maintain the concentration level within the specified range.

To prevent damage to your engine, never add coolant to an overheated engine. Allow the engine to cool first.
If the lift truck is to be stored in, or shipped to, an area with freezing temperatures, the cooling system must be protected to the lowest expected outside (ambient) temperature.

The engine cooling system is protected with a commercially available automotive antifreeze, when shipped from the factory.

Check the specific gravity of the coolant solution frequently in cold weather to ensure adequate protection.

Clean the cooling system if it is contaminated, if the engine overheats or if foaming is observed in the radiator.

Old coolant should be drained, system cleaned and new coolant added as recommended with the commercially available automotive antifreeze.

Filling at over 20 liters per minute can cause air pockets in the cooling system.

After draining and refilling the cooling system, operate the engine with the radiator cap removed until the coolant reaches normal operating

temperature and the coolant level stabilizes. Add coolant as necessary to fill the system to the proper level.

Operate with a thermostat in the cooling system all year-round. Cooling system problems can arise without a thermostat.

Coolant Water

Hard water, or water with high levels of calcium and magnesium ions, encourages the formation of insoluble chemical compounds by combining with cooling system additives such as silicates and phosphates.

The tendency of silicates and phosphates to precipitate out-of-solution increases with increasing water hardness. Hard water, or water with high levels of calcium and magnesium ions encourages the formation of insoluble chemicals, especially after a number of heating and cooling cycles.

DOOSAN prefers the use of distilled water or deionized water to reduce the potential and severity of chemical insolubility.

Acceptable Water	
Water Content	Limits (ppm)
Chlorides (CI)	40 maximum
Sulfates (SO4)	50 maximum
Total Hardness	80mg/ℓ maximum
Total Solids	250 maximum
pH	6.0 ~ 8.0

ppm = parts per million

Using water that meets the minimum acceptable water requirement may not prevent drop-out of these chemical compounds totally, but should minimize the rate to acceptable levels.

Antifreeze

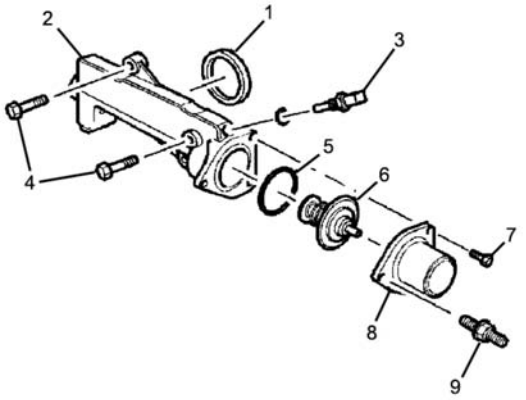
DOOSAN recommends selecting automotive antifreeze suitable for gasoline engines using aluminum alloy parts. The antifreeze should meet ASTM-D3306 standard.

Make proper antifreeze additions.

Adding pure antifreeze as a makeup solution for cooling system top-up is an unacceptable practice. It increases the concentration of antifreeze in the cooling system which increases the concentration of dissolved solids and undissolved chemical inhibitors in the cooling system. Add antifreeze mixed with water to the same freeze protection as your cooling system.

Thermostat Housing

Components



1) Seal 2) Housing 3) Sensor 4) Bolt 5) Seal
6) Thermostat 7) Bolt 8) Inlet-Water 9) Stud

Removal

Remove or disconnect

1. Battery negative cable.

2. Drain the coolant, loosening the radiator lower hose.

3. Electric connection from the temperature sensor.

4. Radiator-to-thermostat upper hose, with a 6-mm socket wrench and handle.

5. Timing belt rear cover; see “Timing Belt Rear Cover – Removal”, in this section.

6. With special clamp pliers, loosen the upper hose from the cab heating pipe, below the intake manifold.

7. Thermostat housing-to-cylinder head attaching bolts, with a 13-mm socket and handle.

8. Pull out the thermostat housing and remove the lower hose to the thermostat housing, with a 10-mm socket wrench and handle.

9. Thermostat housing.

Installation

Install or connect

1. A new “O” ring in the thermostat housing to the cylinder head.

2. Lower hose to the thermostat housing and clamps.

3. Use a 10-mm socket wrench and torque wrench to tighten the clamp.

Tighten

- Clamp: 4 – 5 N·m (3 – 3,6 lb·ft).

4. Thermostat housing and attaching bolts; without tightening.

Obs.: When installing the thermostat housing, the heater pipe upper hose should be placed below the manifold.

5. With a 13-mm socket wrench and torque wrench; tighten the attaching bolts.

Tighten

- 10 – 20 N·m (7 – 15 lb·ft.).

6. Using special clamp pliers, install the upper hose clamp below the intake manifold.

7. Timing belt rear cover; see “Timing Belt - Installation”, in this section.

8. Radiator-to-thermostat upper hose and clamp.

9. With a 6-mm socket wrench and torque wrench; tighten the clamp.

Tighten

- Bolts: 4 – 5 N·m (3 – 3,6 lb·ft.).

10. Temperature sensor electric connection.

11. Refill the cooling system.

12. Battery negative cable.



Water Pump

Removal

Remove or disconnect

1. Drain the coolant loosening the radiator lower hose.

2. Timing belt rear cover; see “Timing Belt Rear Cover – Removal”, in this section.

3. Timing belt Tensioner attaching bolt, with a 13-mm combination wrench.

4. Mark the water pump regarding the cylinder block so as to identify the assembly position.

5. Water pump attaching pump, with a 6-mm Allen wrench and handle.

6. Water pump and “O” ring.

Installation

Install or connect

1. New “O” ring in the water pump.

2. Water pump, observing the mark made in the disassembly to identify the proper assembly position.

3. Water pump attaching bolts, without tightening.

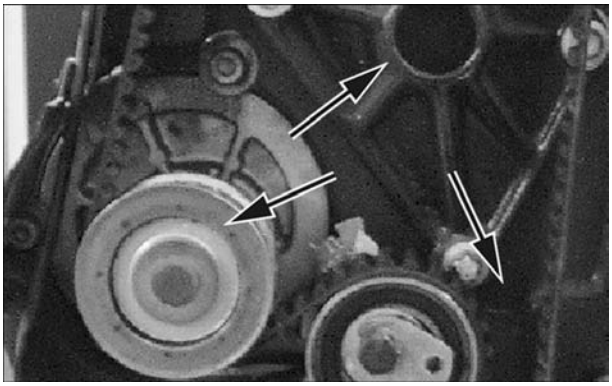
4. With a 6-mm Allen wrench and torque wrench; tighten.

Tighten

- Bolts: 20 – 30 N·m (15 – 22 lb·ft);

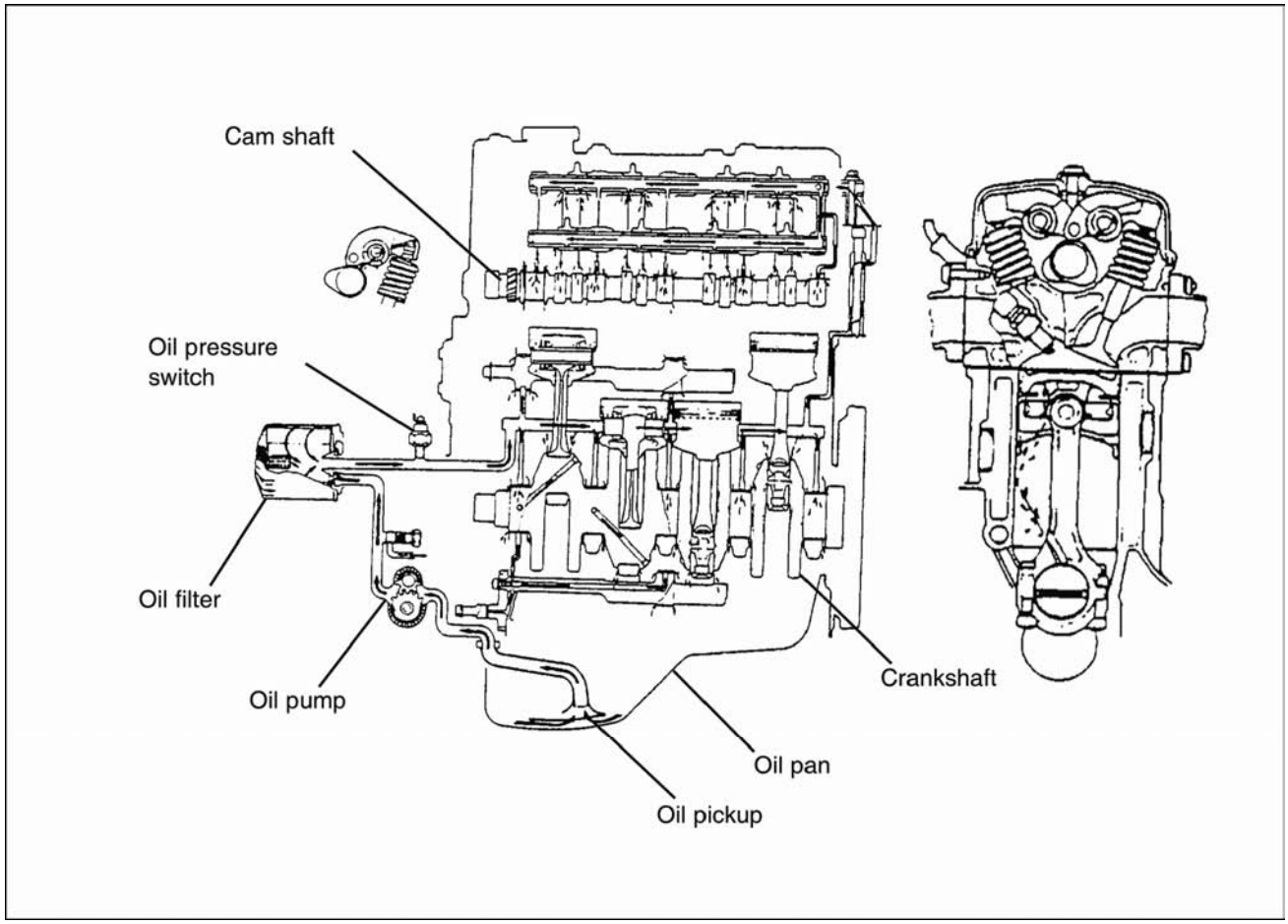
5. Timing belt Tensioner and attaching bolt, without tightening.

6. Timing belt rear cover; see “Timing Belt Rear Cover – Installation”, in this section.



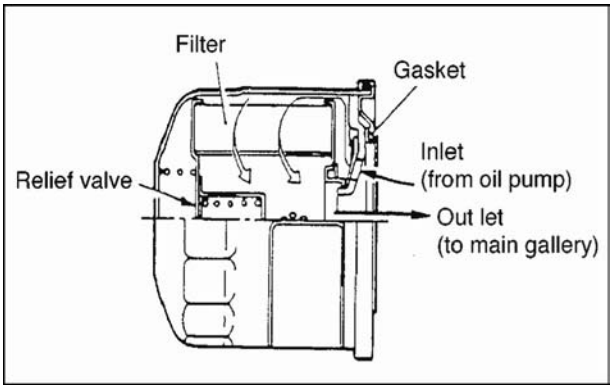
Lubrication System

General Description



Lubricating system is the full-flow filtered pressure-feed oil system and the oil reserved in the oil pan is fed with pressure to each part of engine. After the oil pressure is adjusted through the relief valve, the oil is fed to the cylinder blocks and cylinder head. In the cylinder head the oil is forcibly fed to the camshaft journals, rocker arm pivots and further cam surfaces.

OIl Filter



Testing and Adjusting

Adhere to the following warnings when performing any tests or adjustments while the engine is running.

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

⚠ WARNING

Exhaust fumes contain carbon monoxide (CO) which can cause personal injury or death. Start and operate the engine in a well ventilated area only. In an enclosed area, vent the exhaust to the outside.

Engine Oil

Engine Oil Recommendation

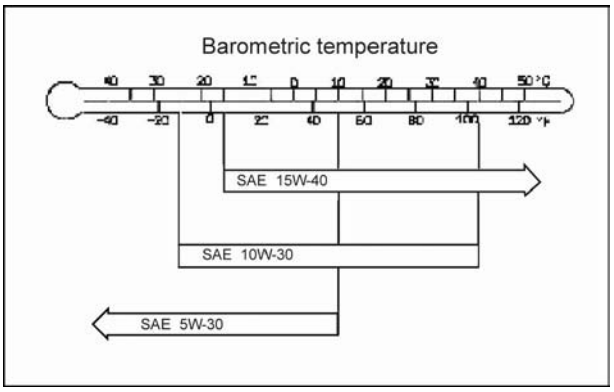
The following oil specifications provide the guidelines for the selection of commercial products : Use gasoline engine oil. Recommended API service classification is class SJ grade.

NOTICE

Failure to follow the oil recommendations can cause shortened engine life due to carbon deposits or excessive wear.

Prior to changing oil, select an oil based on the prevailing daytime temperature in the area in which the engine is operated. The chart in figure is a guide to selection the proper crankcase oil.

IMPORTANT: Oils containing “solid” additives, non-detergent oils, or low-quality oils are not recommended for use in G424F(E) Engine.



Engine Oil Viscosity Recommendation

NOTE: In normal case, the recommended engine oil for G424F(E) engine is SAE 10W - 30.

But, if the excessive valve noise occurs up to five minutes after a cold start and if the maximum ambient temperature is lower than 10°C (50°F), it is recommended to change engine oil to SAE 5W - 30 for that application.

Synthetic Oils

Synthetic engine oils are not recommended for use in G424F(E) Engine. Synthetics may offer advantages in cold-temperature pumpability and high-temperature oxidation resistance.
However, synthetic oils have not proven to provide operational or economic benefits over conventional petroleum-based oils in G424F(E) Engine. Their use does not permit the extension of oil change intervals.

Lubrication System Problems

One of the problems in the list that follows will generally be an indication of a problem in the lubrication system for the engine.

- Too much oil consumption.
- Low oil pressure.
- High oil pressure.
- Too much component wear.

Too Much Oil Consumption

• Engine outside oil leakage

Check for leakage at the seals at each end of the crankshaft. Look for leakage at the oil pan gasket and all lubrication system connections. Check to see if oil comes out of the crankcase breather. This can be caused by combustion gas leakage around the pistons. A dirty crankcase breather will cause high pressure in the crankcase, and this will cause gasket and seal leakage.

• Combustion area oil leakage

Oil leakage into the combustion area of the cylinders can be the cause of blue smoke. There are three possible ways for oil leakage into the combustion area of the stems.

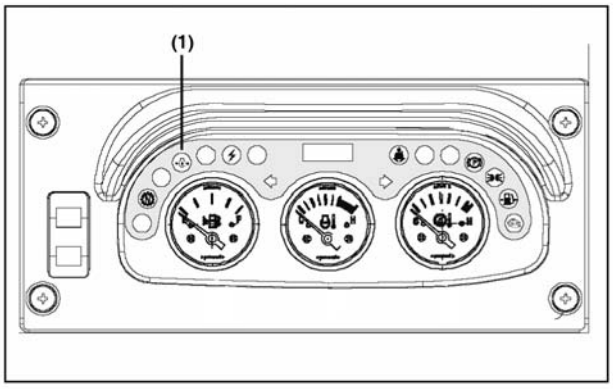
1. Oil leakage between worn valve guides and valve stems.

2. Worn or damaged piston rings, or dirty oil return holes.

3. Compression ring and/or intermediate ring not installed correctly.

NOTE: Too much oil consumption can also be the result if oil with the wrong viscosity is used. Oil with a thin viscosity can be caused by fuel leakage into the crankcase, or by increased engine temperature.

Low Oil Pressure



Instrument Panel
(1) Engine Oil Light

Before starting the engine, the engine oil light(1) on the instrument panel will turn on when the key switch is turned to the ON position. The light will turn off after the engine is started and while the engine is running, lidicating normal oil pressure. The light will turn on during operation only when there is insufficient engine oil pressure to properly lubricate the engine's internal parts.

If the oil light comes on, indicating the pressure is low, check for the causes that follow:

1. Low oil level in the crankcase.

2. Defect in the oil pressure indicator light or oil pressure sensor unit.

3. Restriction to oil pump screen.

4. Leakage at the oil line connections.

5. Worn connecting rod or main bearings. Worn gears in the oil pump.

6. Oil pressure relief valve worn or stuck in the OPEN position.

7. Oil filter bypass valve stuck open. Oil filter is restricted. Replace oil filter.

High Oil Pressure

Oil pressure will be high if the oil pressure relief valve in the oil pump cannot move from the closed position.

Too Much Component Wear

When some components of the engine show bearing wear in a short time, the cause can be a restriction in an oil passage. A broken oil passage can also be the cause.
If an oil pressure check is done and the oil pressure is correct, but a component is worn because it does not get enough lubrication, look at the passage for oil supply to that component. A restriction in a supply passage will not let enough lubrication get to a component and this will cause early wear.

Oil Pan

Removal

Remove or disconnect

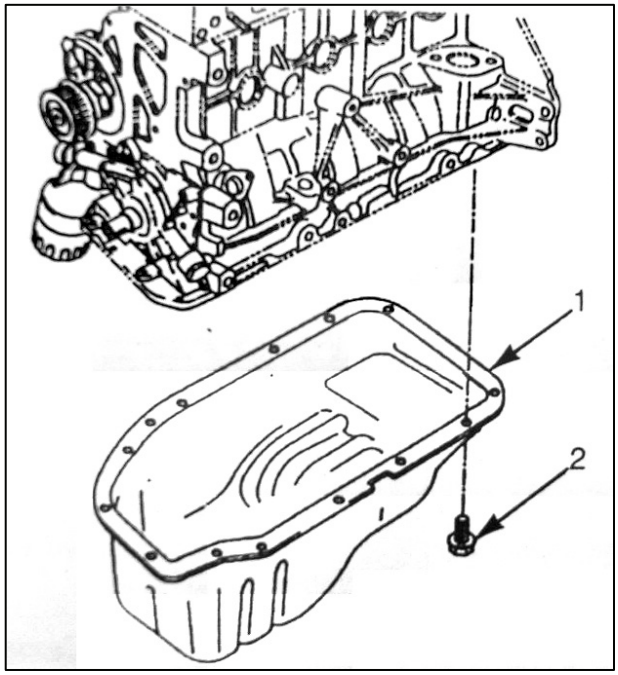
1. Drain the oil on a proper container, removing the oil pan drain plug, with Torx T45 wrench.

2. Position the vehicle on an elevator and raise it.

3. Oil pan guard attaching bolts; with a 13-mm socket wrench, extension and handle, remove the guard.

4. Transmission flange-to-oil pan attaching bolts, with a 18-mm socket wrench and handle.

5. Oil pan-to-cylinder block attaching bolts; with a Torx E12 wrench and handle, remove the oil pan.



Clean

- Gasket residues from the cylinder block and oil pan, taking care not to scratch the mating surfaces of the new gasket.

Inspect

- Oil pan for warping.

Installation

Install or connect

1. Adhesive sealant in the oil pan.

2. Oil pan-to-engine attaching bolts, without tightening.

3. Transmission flange-to-oil pan attaching bolts, without tightening.

4. With an 18-mm socket wrench, extension and torque wrench, tighten the transmission flange-to-oil pan bolts.

Tighten

- Bolts: 18 – 22 N·m (13 – 16 lb·ft.)

5. With a Torx E12 wrench and torque wrench, tighten the oil pan-to-cylinder block bolts.

Tighten

- Bolts: 18 – 22 N·m (13 – 16 lb·ft.)

6. Oil pan plug

7. With the Torx E12 wrench and torque wrench; tighten.

Tighten

- Bolts: 40 – 70 N·m (29 – 51 lb·ft)

8. Oil pan guard and attaching bolts, without tightening.

9. With a 13-mm socket wrench and torque wrench; tighten.

Tighten

- Bolts: 27 – 38 N·m (20 – 30 lb·ft).

10. Lower the vehicle.

11. Refill with specified oil up to the level.

Oil Pump

Removal

Remove or disconnect

1. Timing pulley rear cover; see “Timing Pulley Rear Cover – Removal”, in this section.

2. Crankshaft timing pulley, use a 17-mm socket wrench and handle to remove the attaching bolt.

3. Oil filter.

4. Position the vehicle on an elevator and raise it.

5. Engine oil pan; see “Oil Pan – Removal”, in this Section.

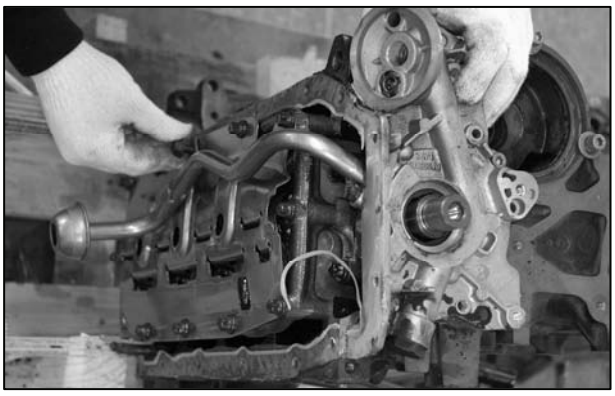
6. Oil screen, with a 10-mm socket wrench and handle, to remove the oil screen-to-oil pump bolt and a Torx 13-mm wrench and handle to remove the oil screen-to- framing grille bolt.

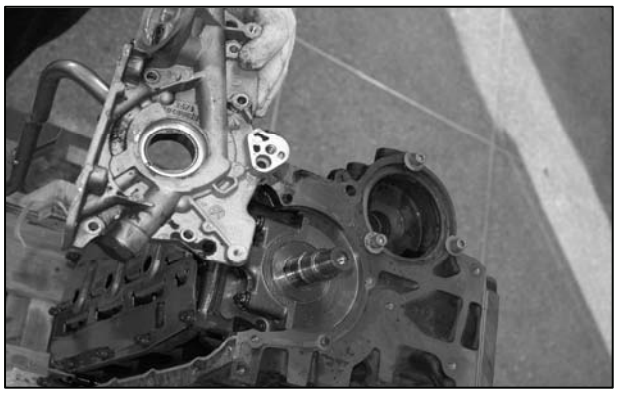
7. Oil pressure sensor electric connection.

8. Timing belt Tensioner attaching bolt, with a 13-mm combination wrench and remove the Tensioner.

9. Oil pump attaching bolt, with a 5-mm Allen wrench.

10. Oil pump.





Installation

Install or connect

1. Oil pump new gasket to the cylinder block.

2. Oil pump to the cylinder block and attaching bolts, without tightening.

3. With a 5-mm Allen wrench and torque wrench, tighten the oil pump attaching bolts.

Tighten

- Bolts: 6 – 10 N·m (4.4 – 7 lb·ft.).

4. Oil screen to the oil pump and attaching bolts, without tightening.

5. Oil screen-to-framing grille attaching bolt, without tightening.

6. With a Torx E12 wrench and torque wrench, tighten the oil screen-to-framing grille attaching bolt.

Tighten

- Bolt: 4 – 10 N·m (3 – 7 lb·ft.).

7. With a 10-mm socket wrench and torque wrench, tighten the oil screen-to-oil pump attaching bolts.

Tighten

- Bolts: 6 – 12 N·m (4.4 – 8.8 lb·ft.).

8. Oil filter.

9. Oil pan; see “Oil Pan – Installation”, in this section.

10. Oil pressure sensor electric connection.

11. Timing belt automatic Tensioner and attaching bolt, without tightening.

Important

- The Tensioner roller lug (1) should be positioned in the guide housing (2) of the oil pump case.

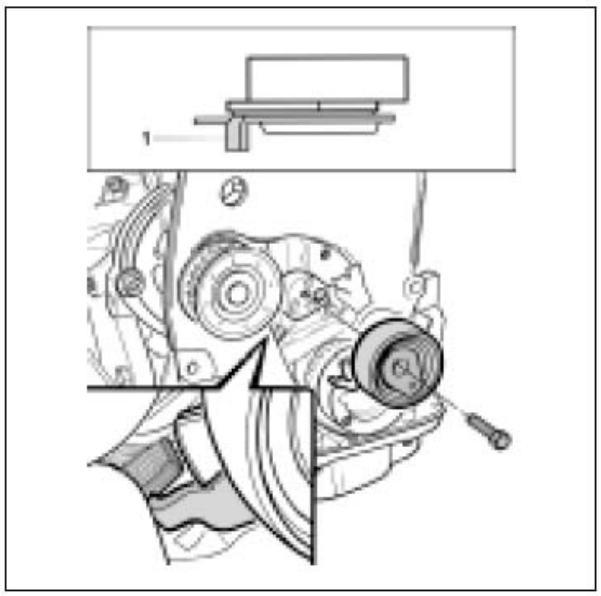
12. Crankshaft timing pulley and attaching bolt, without tightening.

13. With a 17-mm socket and torque wrench.

Tighten

- Bolts: 135 + 30° + 15° (99 lb·ft. + 30° + 15°).

14. Timing pulley rear cover; see “Timing Pulley Rear Cover – Installation”, in this section.



Oil Pump Assembly

Disassemble

1. Remove the oil pump; see “Oil Pump – Removal”, in this section.

2. Pump cover, with a proper posi-drive screwdriver.

3. Drive gear.

4. Driven gear.

5. Oil pressure switch, with a 26-mm wrench.

6. Oil filter gallery plug, with a 19-mm combination wrench.

7. Relief valve plug, with a 24-mm combination wrench.

8. Sealing washer.

9. Spring.

10. Valve plunger.

Clean

- All pump parts.

Inspect

- Parts for wear.

Measure

Play between the following parts:

- Driven gear and case, which should be 0.11 – 0.19 mm.
- Drive gear and crescent, which should be 0.35 – 0.45 mm.
- Gear and cover, which should be 0.03 – 0.10 mm.

Assemble

1. Plunger in the valve. (1)

2. Spring. (2)

3. Sealing washer. (3)

4. Relief valve plug, with a 24-mm socket wrench and torque wrench.(4)

Tighten

- Valve plug: 45 – 60 N•m (33 – 44 lb•ft).

5. Driven gear. (5)

6. Drive gear. (6)

7. Oil pump cover and attaching screws, with a posi-drive screwdriver. (7)

8. Oil pump gallery plug, with a torque wrench. (8)

Tighten

- Gallery plug: 30 – 35 (22 – 25,7 lb·ft)

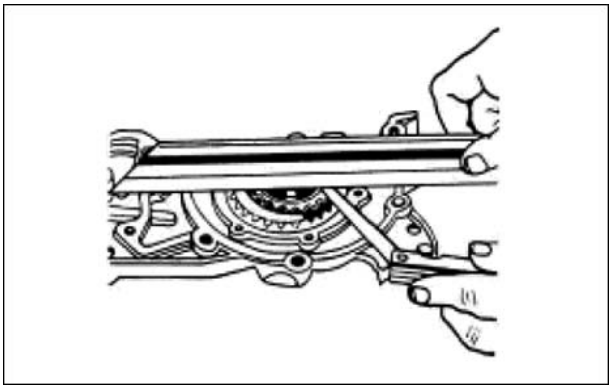
9. Oil pressure switch, with a 26-mm socket and torque wrench.

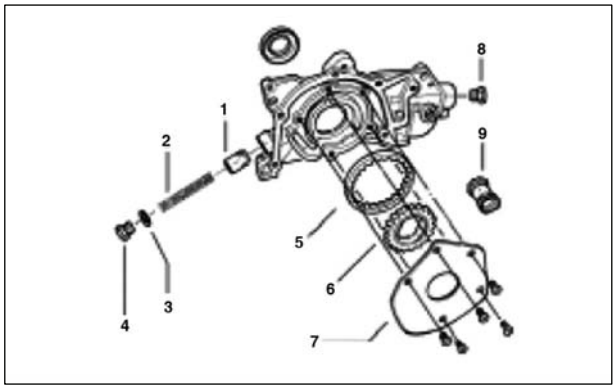
Tighten

- Switch: 30 – 50 N·m (22 – 36,7 lb·ft)

10. Install the oil pump; see “Oil Pump – Installation”, in this section.







Camshaft Case Assembly

Removal

Remove or disconnect

1. Depressurize the fuel system:

- Fuel-off solenoid valve disconnect.
- Run the engine and leave it running until stopping by lack of fuel.
- Run the engine for about 5 seconds so as to fully depressurize the fuel system.
- Fuel pump electric connection, from the tank upper area
- Run the engine and let it idle until it stops by lack of fuel.
- Start the engine for about 5 seconds, so as to obtain full pressure relief in the fuel system.

2. Battery negative cable.

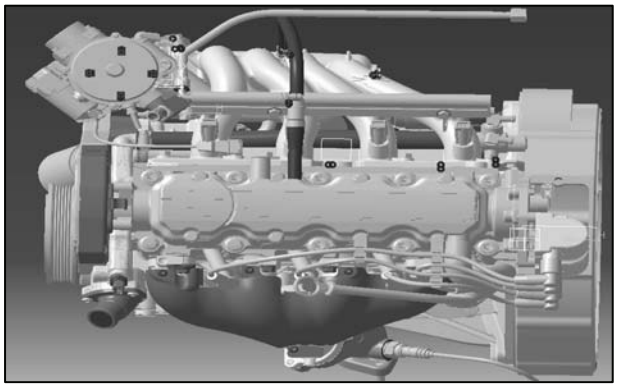
3. Hose connecting the Mixer assembly to the air cleaner, with an 8-mm socket wrench, extension and handle; loosen the clamps.

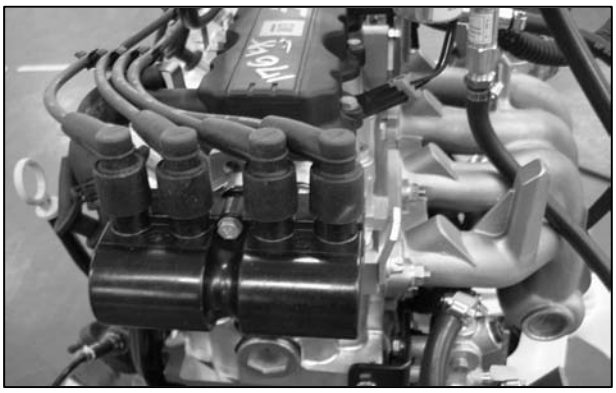
4. Electric harness-to-intake manifold front area support, with a 10-mm socket wrench, extension and handle; position the harness so that it does not obstruct the manifold removal.

5. MAP electric connection, located on the intake manifold rear area.

6. DIS coil electric connection and spark plug cables.

7. DIS coil attaching bolts, with a 10-mm combination wrench and handle; remove the DIS coil.





8. Camshaft cover-to-cylinder block breather hose, with special clamp pliers.

9. Ground cable from the camshaft case lower rear area with a Torx E12 wrench.

10. Harness support and hose support from the intake manifold side, with a 13-mm combination wrench.

11. Timing belt rear cover; see “Timing Belt Rear Cover – Removal”, in this section.

12. Generator support-to-intake manifold attaching bolt, with a 6-mm Allen wrench.

13. Air conditioning upper support, with a Torx E12 wrench to loosen the attaching bolt, support-to-manifold stud upper nuts, with a 15-mm socket wrench and handle.

14. Drain the coolant, loosening the radiator lower hose.

15. Radiator-to-thermostat upper hose, loosening the thermostat clamp with a 6-mm socket wrench and handle.

16. Hot air hose from cab to pipe, with special clamp pliers.

17. Heat sink attaching bolts, with a 10-mm socket wrench and handle.

18. Exhaust heat sink.

19. Exhaust pipe-to-exhaust manifold attaching bolts, with a 13-mm socket wrench and handle.

20. Hot air pipe attaching bolt, from the cylinder block, with a 13-mm socket wrench, extension and handle.

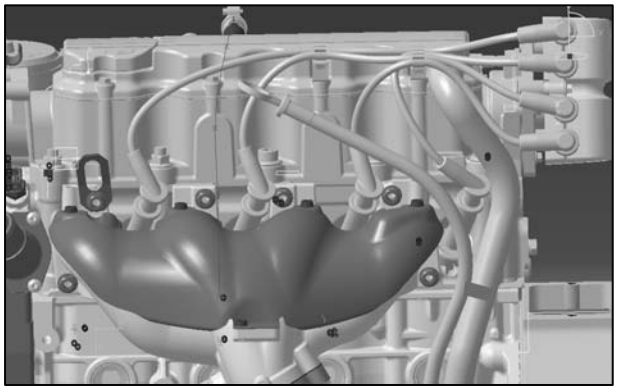
21. Hot air pipe hose clamp-to-radiator lower hose attaching bolt, with a 7-mm socket wrench and handle.

22. Hot air pipe hose.

23. Thermostat pipe; see “Thermostat Pipe – Removal”, in this Section.

24. Cylinder head-to-cylinder block bolts, with a Torx T-55 wrench, extension and handle; for the front bolts, use a 19-mm socket wrench, extension and handle.

Obs.: Loosen the bolts in the sequence shown, loosening 1/4 of a turn, 1/2 turn and next removing them.

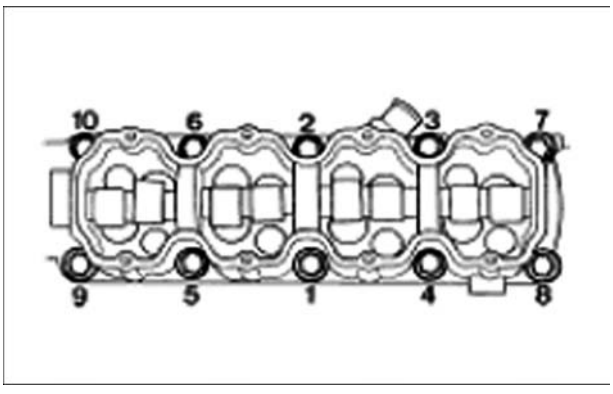


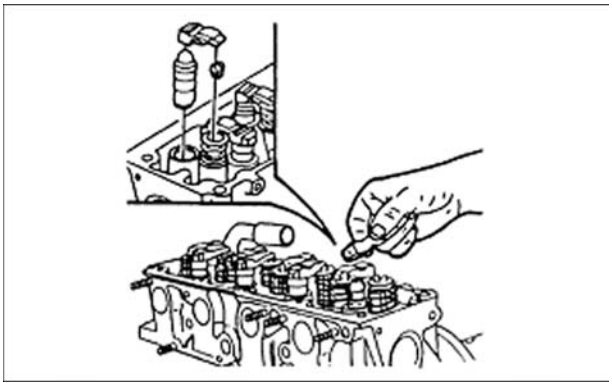
25. Camshaft case.

26. Rocker arms, linkages and valve lifters, without mixing them, so that they may be assembled in the same position.

27. Cylinder head with intake and exhaust manifolds, which are attached on the same, and the cylinder head gasket.

Obs.: The cylinder head should be removed due to the replacement of the gasket by a new one.





28. Attach the camshaft case on a vise.

Obs.: Use protecting jaws in the vise.

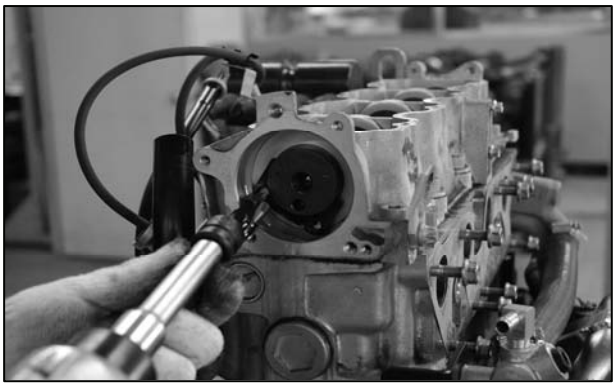
29. Camshaft rear cover attaching bolt, with a 10-mm wrench combination wrench.

30. Camshaft case rear cover and gasket.

31. Camshaft lock-to-case attaching bolts, with a 5-mm Allen wrench.

32. Lock; for that, displace the camshaft a little to the outside.

33. Camshaft, by its rear side.



Installation

Install or connect

1. Camshaft in the case.

Important

- Despite the camshaft end being chamfered, take care not to damage the seal.
- When installing a new camshaft, drain the engine oil, apply zinc ditiophosphate additive in the camshaft lobes and rocker arms and add the remaining additive to the new engine oil.

2. Camshaft lock and attaching bolt, without tightening.

3. With a 5-mm Allen wrench and torque wrench, give the final tightening.

Tighten

- Bolts: 4 – 10 N·m

4. Camshaft case rear cover, with a new gasket and attaching bolts, without tightening.

5. With a 10-mm socket wrench and torque wrench, give the final tightening.

Tighten

- Bolts: 6 – 10 N·m

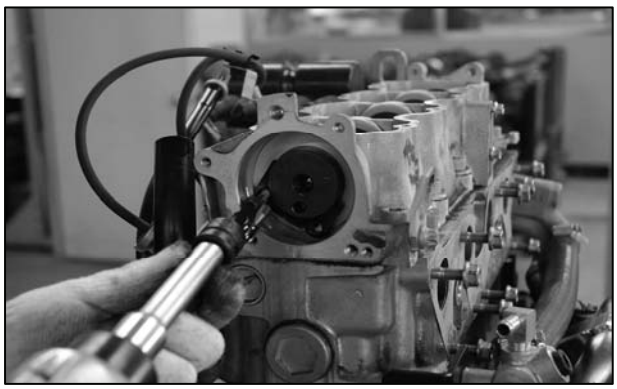
6. New cylinder head gasket to the cylinder block.

7. Cylinder head together with the exhaust and intake manifolds, positioning them in the cylinder block.

8. Valve lifters, pad and rocker arms.

9. Camshaft case with the camshaft assembled.

10. Camshaft and cylinder head new attaching bolts, without tightening.









11. With a Torx T-55 or 19-mm socket wrench, according to the bolt and a torque wrench, give the final tightening to the bolts, observing the tightening sequence.

Tighten

- Bolts: 25 N·m (18 lb·ft) + 180° + 10°

12. Camshaft cover and attaching bolts, without tightening, observing that on the left side, the center bolts should be installed together with bolts and spark plug cable support.

13. With a 13-mm socket wrench and torque wrench, give the final tightening.

Tighten

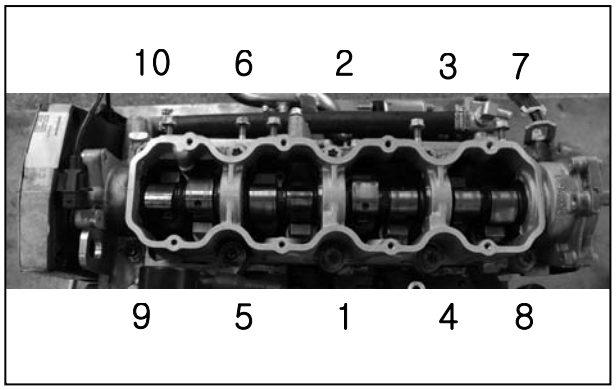
- Bolts: 4 – 10 N·m (3 – 7 lb·ft.)

14. New gasket between exhaust pipe and exhaust manifold and attaching bolts, without tightening.

15. With a 13-mm socket wrench, extension and torque wrench; tighten.

Tighten

- Bolts: 14 – 20 N·m (10 – 15 lb·ft.)



16. Thermostat; see “Thermostat – Installation”, in this section.

17. Hot air pipe hose, together with clamp, in the radiator lower hose.

18. With a 7-mm socket wrench, extension and torque wrench; tighten.

Tighten

- Clamp: 4 – 5 N·m (3 – 3,6 lb·ft)

19. Hot air pipe support, in the cylinder block, with the attaching bolt, without tightening.

20. With a 13-mm socket wrench, extension and torque wrench; tighten.

Tighten

- Bolt: 12 – 18 N·m (8,8 – 13 lb·ft)

21. Cab-to-hot air pipe hoses and clamp, with special clamp pliers.

22. Radiator-to-thermostat upper hose, with its clamp.

23. With a 6-mm socket wrench and torque wrench; tighten.

Tighten

- Clamp: 4 – 5 N·m (3 – 3,6 lb·ft)

24. Air conditioning upper support and attaching bolts.

25. With a Torx E12 wrench and torque wrench, tighten the bolt attaching the upper support to the air compressor support.

Tighten

- Bolt: 18 – 28 N·m (13 – 20.5 lb·ft.)

26. With a 15-mm socket wrench and torque wrench, tighten the nuts attaching the upper support to the cylinder head.

Tighten

- Nuts: 25 – 30 N·m (18 – 22 lb·ft.)

27. Timing belt rear cover; see “Timing Belt Rear Cover – Installation”, in this section.

28. Harness and hose supports and attaching bolt, without tightening, to the intake manifold side.

29. With a 13-mm socket wrench and torque wrench; tighten.

Tighten

- Bolt: 7 – 8 N·m (5 – 5,8 lb·ft)

30. Ground cable, to the camshaft case lower rear area and attaching nut, without tightening.

31. With a Torx E12 wrench and torque wrench; tighten.

Tighten

- Bolt: 18 – 22 N·m (13 – 16 lb·ft)

32. DIS coil together with the spark plug cables and attaching bolt, attaching it with a 10-mm combination wrench.

33. DIS coil electric connection.

34. MAP sensor electric connection.

35. Electric harness support to the intake manifold front area and attaching bolt, without tightening.

36. With a 10-mm socket wrench, extension and torque wrench; tighten.

Tighten

- Bolt: 7 – 8 N·m (5 – 5,8 lb·ft)

37. Radiator lower hose, with clamp, with special clamp pliers.

38. Hose connecting the throttle valve body (mixer) to the air cleaner, with its clamp.

39. Refill the cooling system.

40. Battery negative cable.

41. Change the engine oil, in view of possible water contamination.

Cylinder Head

Removal

Remove or disconnect

1. Camshaft case assembly; see “Camshaft Case Assembly – Removal”, in this section.

2. Intake manifold-to-cylinder head attaching bolts, with a 13-mm socket wrench, extension and handle.

3. Exhaust manifold-to-cylinder head attaching nuts, with a 13-mm socket wrench, extension and handle.

Clean

- Gasket residues from the exhaust and intake manifolds, taking care not to scratch the gasket mating surfaces.

Installation

Install or connect

1. A new exhaust manifold-to-cylinder head gasket.

2. Exhaust manifold to cylinder head and attaching nuts, without tightening.

3. With a 13-mm socket wrench, extension and torque wrench; tighten.

Tighten

- Nuts: 18 – 22 N·m (13 – 16 lb·ft.)

4. A new gasket between intake manifold and cylinder head.

5. Intake manifold and attaching bolts, without tightening.

Obs.: Do not install the last intake manifold lower nut.

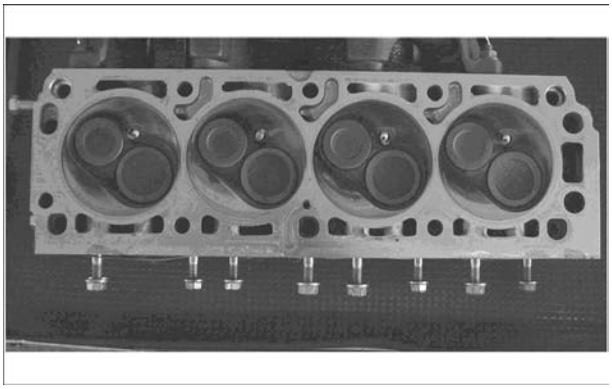
6. With a 13-mm wrench, extension and proper torque wrench; tighten.

Tighten

- Nuts: 18 – 22 N·m (13 – 16 lb·ft.)

Obs.: Tighten the intake manifold nuts in a crisscross sequence, from the center to the ends.

7. Camshaft case assembly; see “Camshaft Case Assembly – Installation”, in this section.



Valve, Spring or Seal

Removal

Remove or disconnect

1. Camshaft case assembly, as per instructions under “Camshaft Case Assembly – Removal”, in this section.

2. Intake manifold-to-cylinder head nuts, with a 13-mm socket wrench, extension and handle and remove the manifold.

3. Exhaust manifold-to-cylinder head nuts, with a 13-mm socket wrench, extension and handle; remove the exhaust manifold.

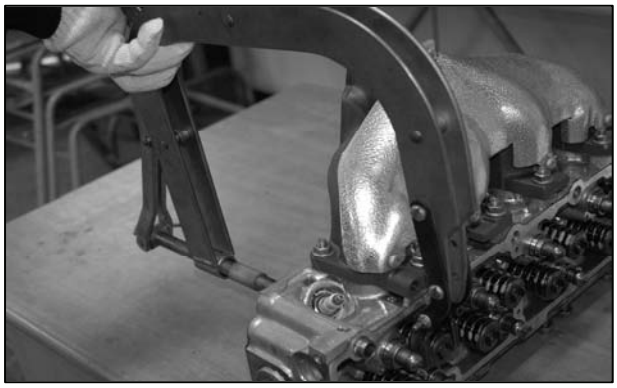
4. Valve lock, with the aid of valve spring compressor.

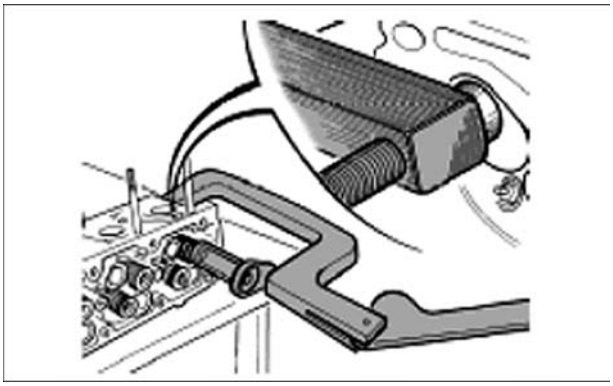
5. Spring plate.

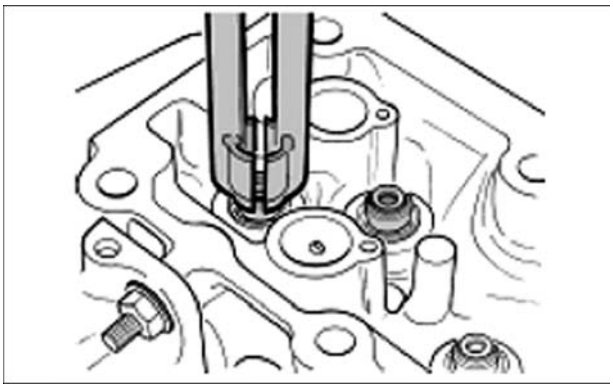
6. Spring.

7. Seal, with seal pliers.

8. Valve.







Inspect

- Cylinder head for cracks in the exhaust passages and combustion chambers.
- Valves for head burning, face cracks and damaged stems.
- Stem lash in the guide, as follows:
  Measure the stem diameter in the upper, center and lower areas.

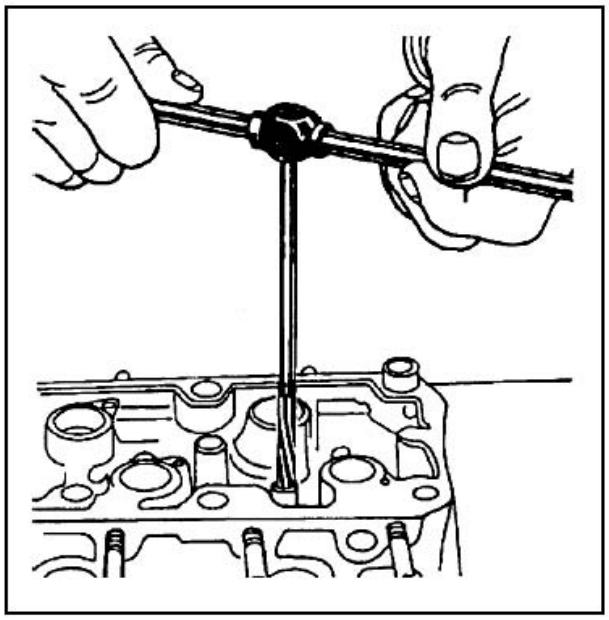
With the telescope gauge in the valve guide, measure in the upper, center and lower areas. The difference in the guide and stem measurements is the lash.

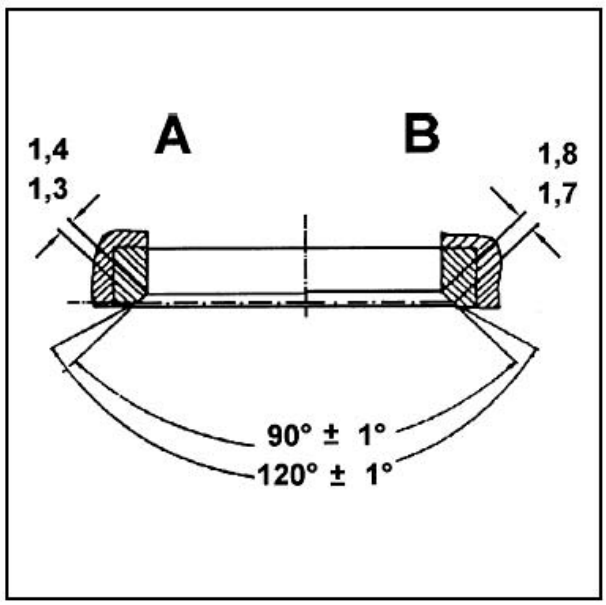
Important

- If the lash is out of the specification, which is 0.015 – 0.042 mm (intake) and 0.038 – 0.072 mm (exhaust), ream the guide to install an oversize valve.

- Valve seat for:

Concentricity between maximum and minimum readings, which should be 0.05 mm (0.002 in.)
Width, which should be 1.3 – 1.4 mm (intake A) and 1.7 – 1.8 mm (exhaust B)





Important

- If necessary use a 45° ± 3° Valves for corrosion. Corroded valves, once not excessively worn, can be refaced by special equipment, as follows:
  Reface them until obtaining a 92 ° ± 15° angle. The face angle can also be considered regarding the valve head, which should be 44°.

Installation

Install or connect

1. Valve seal, with the aid of tool KM-352.

2. Spring and spring plate.

3. Valve lock, with the aid of valve spring compressor.

4. Exhaust manifold with a new gasket to the cylinder head and use new nuts, without tightening.

5. With a 13-mm socket wrench, extension and torque wrench, tighten.

Tighten

- Nuts: 18 – 22 N·m (13 – 16 lb·ft.)

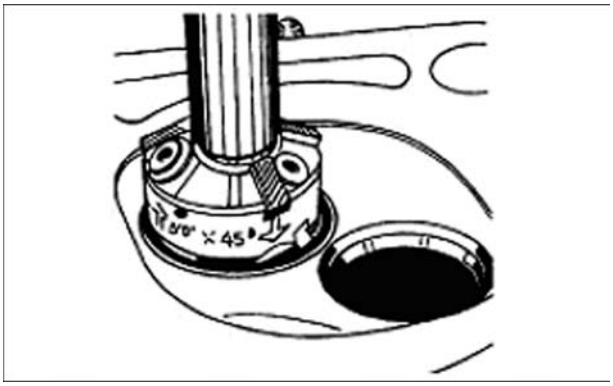
6. Intake manifold with a new gasket to the cylinder head and use new nuts, without tightening.

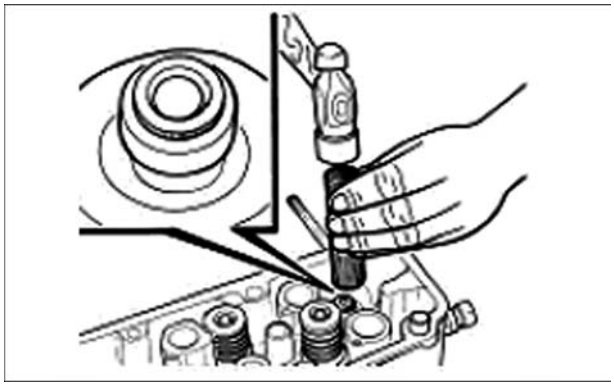
7. With a 13-mm socket wrench, extension and torque wrench, tighten.

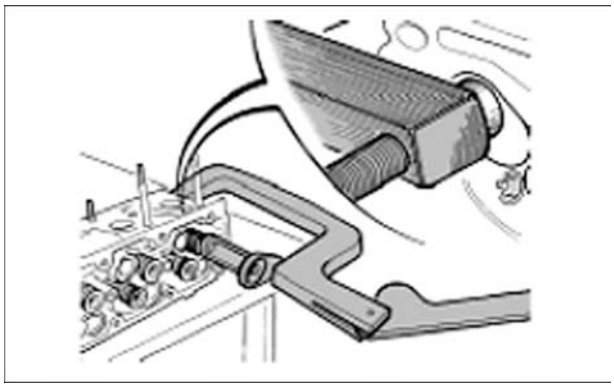
Tighten

- Nuts: 18 – 22 N·m (13 – 16. lb·ft.)

8. Camshaft case assembly; see “Camshaft Case Assembly – Installation”, in this section.







Engine Disassembly

Removal

Remove or disconnect

1. Engine assembly, as per instructions under "Engine Assembly – Removal", in this Section.

2. Generator attaching bolts, with a 13-mm wrench; remove the generator.

3. Power steering pump attaching bolts, with a 13-mm wrench; remove the pump.

4. Exhaust manifold nuts, with a 13-mm socket wrench, extension and handle; remove the exhaust manifold.

5. Intake manifold nuts, with a 13-mm socket wrench, extension and handle; remove the intake manifold.

6. Crankcase vent tube attaching bolt, with a 13-mm socket wrench, extension and handle; remove the crankcase vent tube.

7. Align the camshaft timing pulley mark with the timing belt rear cover mark.

8. Align the crankshaft timing pulley mark with the oil pump case flange mark.

9. Timing pulley front cover attaching bolts, with a 10- mm socket wrench, extension and handle; remove the front cover.

10. Timing belt Tensioner bolt, to relieve the tension of the belt, with a 13-mm combination wrench; remove the timing belt.

Obs.: Turn the crankshaft 45° clockwise, so as to prevent damaging the engine and cylinder head inner components.

11. Camshaft cover attaching bolts, with a 10-mm socket and handle; remove the camshaft cover.

12. Camshaft pulley attaching bolt, using a 17-mm combination wrench and a 22-mm wrench to attach the camshaft; remove the camshaft pulley.

13. Install tool S-9407182 and attach the engine flywheel; with a 19-mm combination wrench, attach the tool bolt.

14. Crankshaft timing pulley attaching bolt, with a 17-mm socket wrench and handle; remove the bolt.

15. Crankshaft timing pulley.

Obs.: If necessary, install gear puller using proper bolts which are supplied with the tool. With a 19-mm combination wrench, turn the tool bolt until removing the crankshaft timing pulley.

16. Timing belt expander, removing the already loose attaching bolt.

17. Timing pulley rear cover attaching bolts, with a 10-mm socket wrench; remove the rear cover.

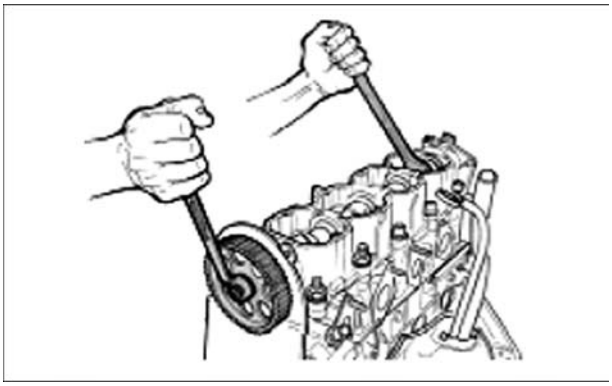
18. Thermostat housing attaching bolts, with a 13-mm socket wrench and handle; remove the thermostat housing.

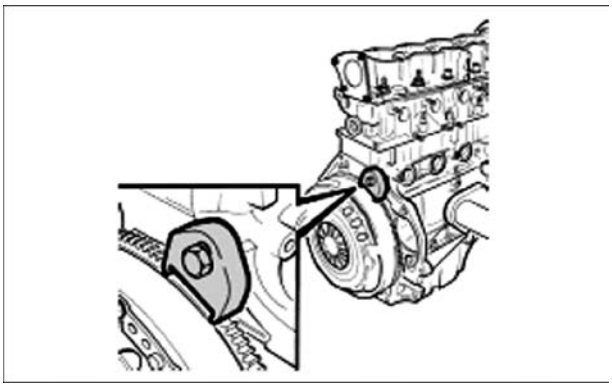
19. Thermostat housing seal ring.

20. Water pump attaching bolt, with a 6-mm Allen wrench and handle; remove the water pump and seal washer.

Obs.: Put a mark on the water pump to engine block, to identify the assembly position.

21. Crankshaft position sensor attaching bolt, with a Torx E10 and handle; remove the crankshaft position sensor.





22. Spark plugs, with a proper wrench.

23. Clutch assembly attaching bolts, with a 10-mm socket wrench, extension and handle. Remove the whole clutch assembly.

24. Flywheel attaching bolt, with a 17-mm socket wrench and handle; remove the flywheel.

Obs.: Remove tool S-9407182 with a 19-mm combination wrench.

25. Cylinder head attaching bolts, with a Torx T-55 wrench, extension and handle.

Important:

- Loosen the bolts in the indicated sequence at of a turn, turn and then removing them.

Obs.: Two bolts are removed by using a 19-mm socket wrench, extension and handle.

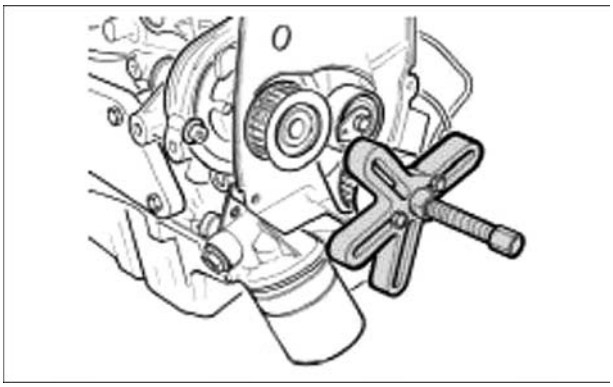
26. Camshaft case.

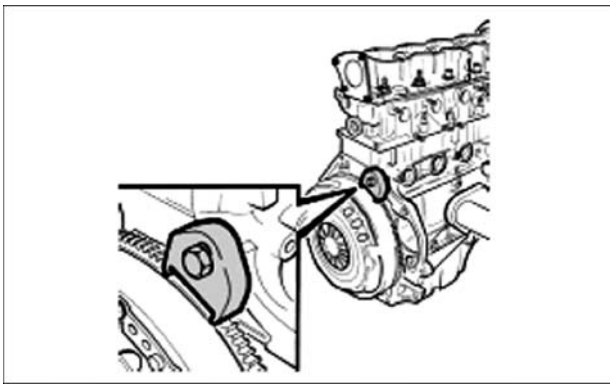
27. Rocker arms, linkages and valve lifters, without mixing them, so that they may be further assembled in the same position.

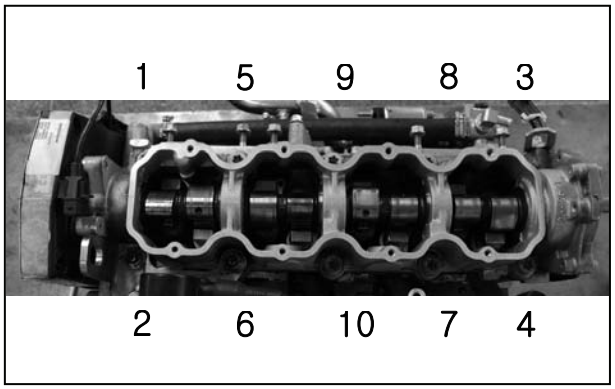
28. Camshaft and gasket.

29. Turn the engine 180° to have access to the engine oil pan.

30. Oil pan attaching bolts, with a Torx E12 wrench, extension and handle; remove the engine oil pan.





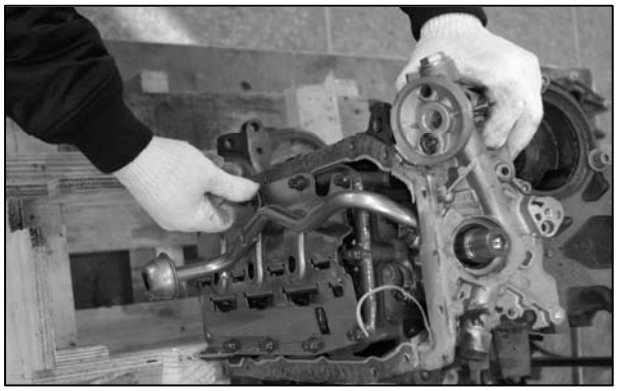


31. Oil strainer attaching bolt, with a 10-mm socket wrench and handle. Remove the oil strainer flange bolts and Torx E12. Loosen the oil stranger stem attaching bolt.

32. Baffle plate and balancer attaching bolts, with a Torx E12 wrench and handle. Remove the baffle plate and balancer.

33. Oil pump attaching bolts, with a 5-mm Allen wrench; remove the oil pump.

34. Install two flywheel attaching bolts in the crankshaft, to rotate the latter and ease the access to the connecting rod attaching bolts.



35. With a punch, identify the connecting rod bearing and connecting rod, according to the cylinder regarding the connecting rod.

36. Turn the crankshaft until the first and four th connecting rods remain with their attaching bolts turned upward.

37. First and fourth connecting rod bearing attaching bolts, with a 14-mm socket wrench, extension and handle; remove the connecting rod caps.



38. Install tool T-9806681 in the connecting rod and remove the piston.

Obs.: Repeat this procedure to remove the other piston.

39. Turn the crankshaft until the second and third connecting rods stay with the attaching bolt turned upward.

40. Second and third connecting rod bearing attaching bolt, with a 14-mm socket wrench, extension and handle; remove the connecting rod caps.



41. Install tool T-9806681 in the connecting rod and remove the piston.

Obs.: Repeat this procedure to remove the other piston.

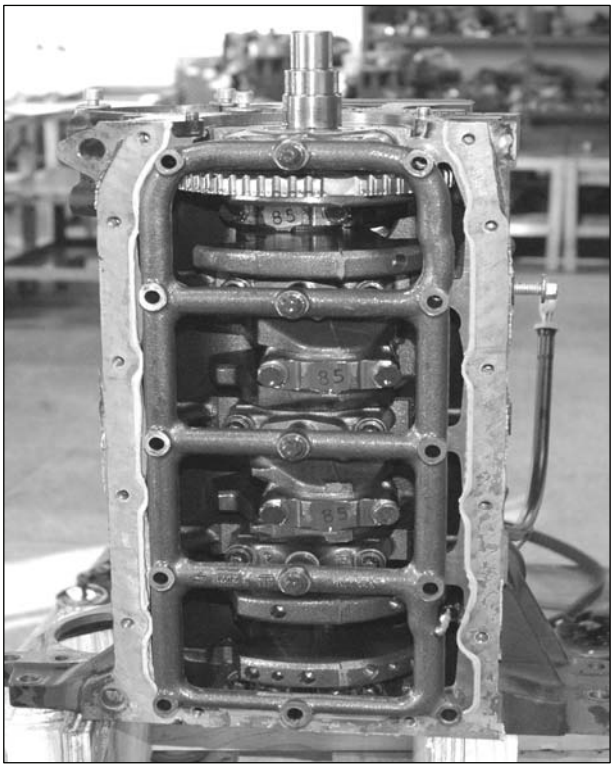
42. Crankshaft seal.

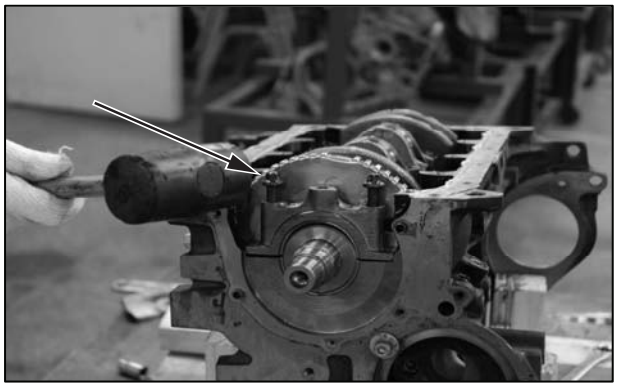
43. Crankshaft bearing attaching bolts, with a 12-mm Torx Bit wrench, extension and handle; remove the crankshaft bearings.

Obs.: If the bearings are stuck, slightly tap with a plastic mallet in both directions, so as to release them.

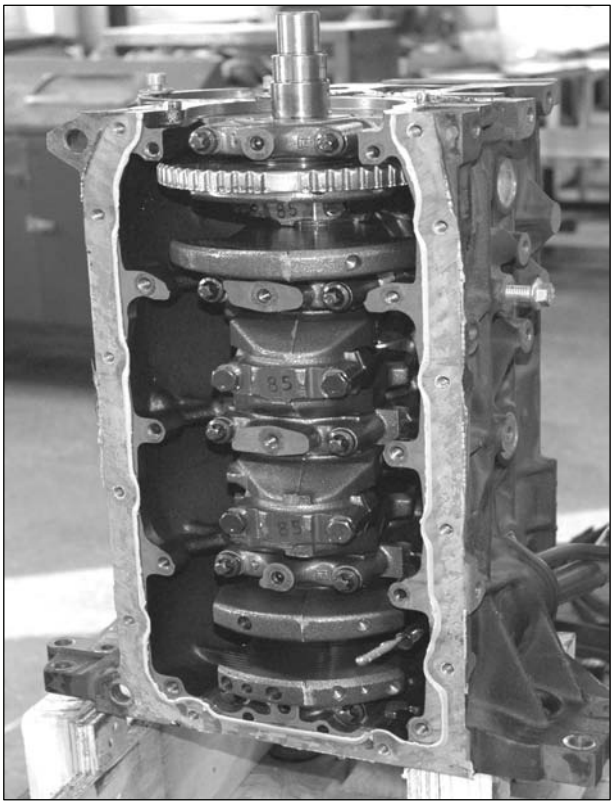
44. Remove the crankshaft.

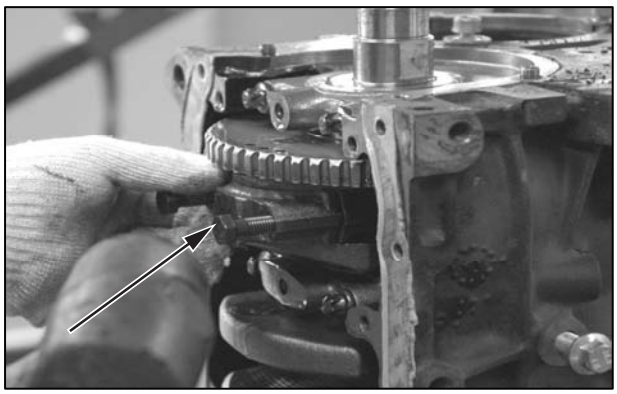


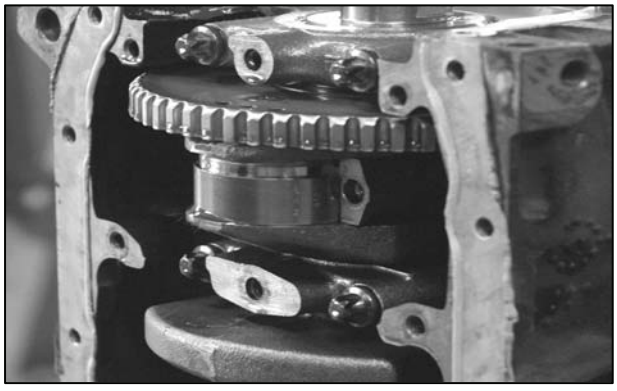






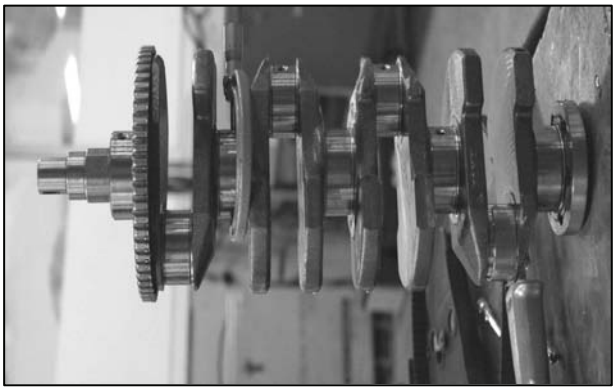






Important:

- Whenever the crankshaft is removed, it should be positioned standing up in the flywheel, to prevent it from warping.



Engine Assembly

Installation

Install or connect

1. Upper shells in the block; lubricate the surface turned toward the saddle with engine oil.

2. Crankshaft in the cylinder block.

3. Main bearing caps with the shells lubricated on the surfaces turned to the saddle.

Important

- The bearing caps should be installed so that the cast number bases (1) stay turned to the engine rear side. Pay also attention to the engraved sequence numbers (2).

- Fill the rear bearing cap side grooves with sealant.

4. Main bearing attaching bolts, without tightening, with a Torx E12 wrench, extension and handle.

Important

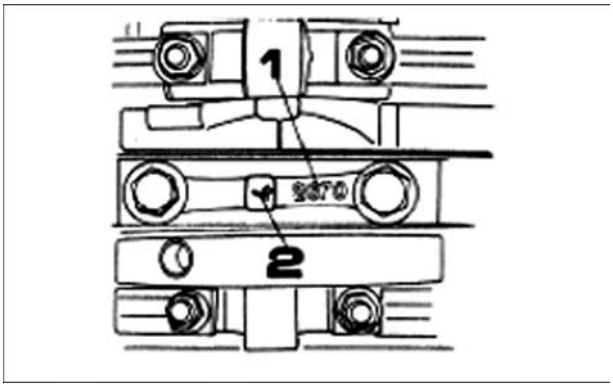
- With a plastic mallet, slightly tap the crankshaft, on both directions, so as to mainly seat the thrust bearing rear face.

5. Tighten the main bearing attaching bolts with a Torx E12 wrench, extension and torque wrench.

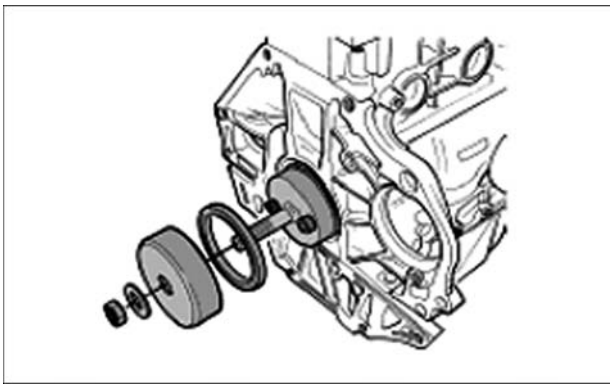
Tighten

- Bolts: 50 N·m + 45° + 15°.

6. Crankshaft seal, with tool KM-658.







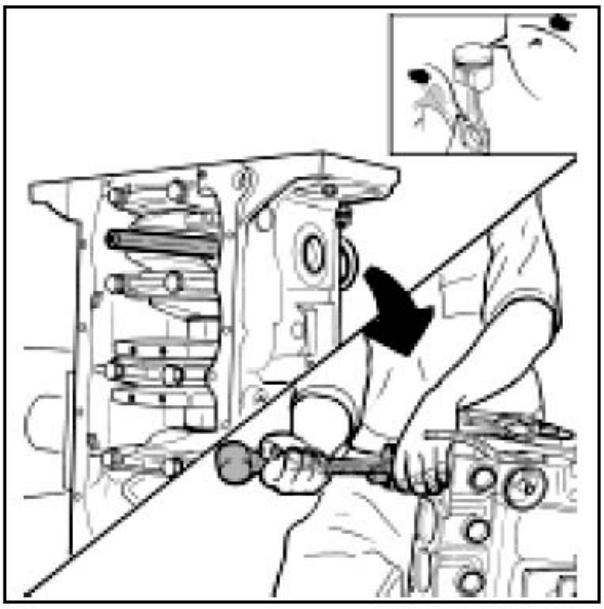
7. Piston-connecting rod assembly in block, with the aid of the universal band, position the piston arrow turned toward the front end of the engine.

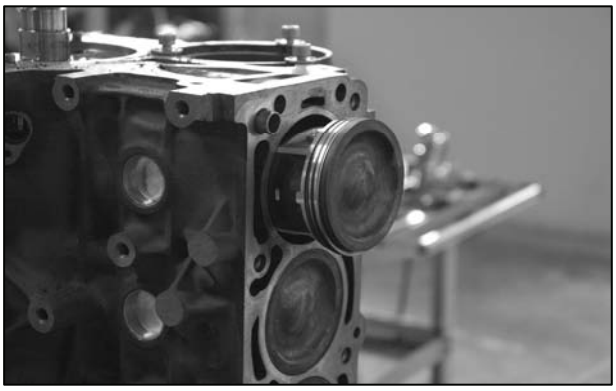
Important

- Lubricate the rings and cylinders.

- Simultaneously, guide the connecting rod bearing with tool T-9806681.

- Install the connecting rod upper shell lubricated only in the face turned to the bearing journal and pull the connecting rod until it touches the journal.





8. Connecting rod cap with the lower shell lubricated only in the face turned to the bearing journal.

9. Connecting rod cap bolts, without fully tightening, with a 14-mm socket wrench and handle.

Important

- Rotate the crankshaft some turns so as the connecting rods stay perfectly seated.

10. Tighten the connecting rod cap attaching bolts with a 14-mm socket wrench and torque wrench.

Tighten

- Connecting rod cap bolts:.....30 – 40 N·m (22 – 29.5 lb·ft.) + 40° to 45°

11. A new gasket to the oil pump.

12. Oil pump to cylinder block and attaching bolts, with a 5-mm Allen wrench and torque wrench.

Tighten

- Bolts: 4 – 10 N·m (3 – 7 lb·ft.).

13. Balancer and baffle plate and attaching bolts, with a Torx E12 wrench and torque wrench.

Tighten

- Bolts: 19 – 21·N.m (14 – 15.5 lb·ft.)

Obs.: One of the bolts only can be installed and tightened after the oil strainer is installed.

14. Oil strainer and attaching bolts in the oil pump, with a 10-mm socket wrench and torque wrench; tighten.

Tighten

- Bolts: 4 – 10 N·m (3 – 7 lb·ft.)

15. Adhesive sealant in the cylinder block and install the oil pan and attaching bolts, with a Torx E12 wrench and torque wrench; tighten.

Tighten

- Bolts: 6 – 10 N·m (4.5 – 7 lb·ft.).

16. Oil filter

Obs.: Tighten only with the hands.

17. Turn engine stand 180° so that the engine stay with the pistons turned upward.

18. A new gasket in the cylinder head, with the TOP mark turned upward and to the engine front end.

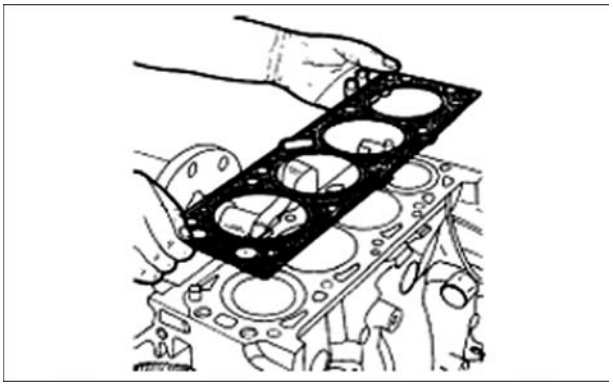
Obs.: Whenever necessary to remove the cylinder head, a new gasket and new bolts should be used for the reassembly.

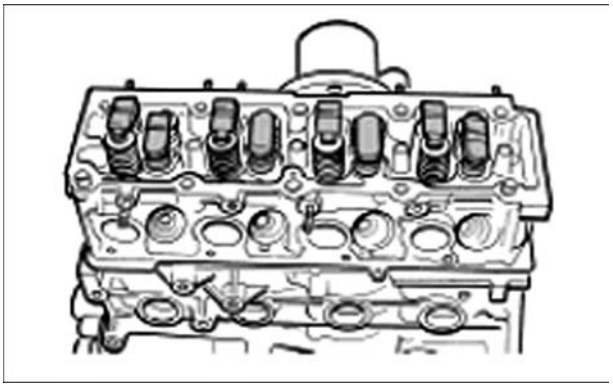
19. Cylinder head.

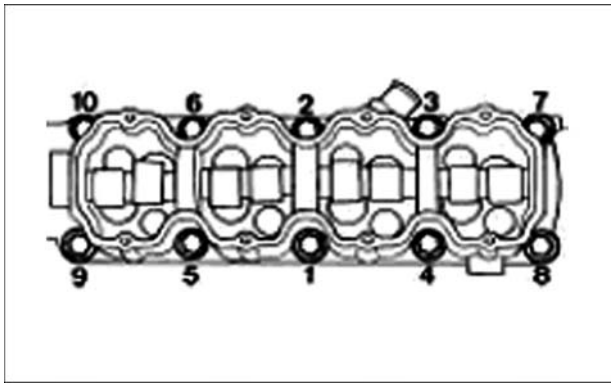
20. Valve lifters, linkages and rocker arms, lubricated with molybdenum bisulfate compound.

Important

- Apply sealing compound in the surface where the camshaft will be seated.







21. Camshaft case.

22. New cylinder head attaching bolts, in the indicated sequence, with a Torx E55 wrench and torque wrench.

Tighten

- Bolts: 25 N·m (18 lb·ft.) + 180° + 10°.

23. A new “O” ring in the water pump.

24. Water pump and attaching bolts, with a 6-mm Allen wrench and torque wrench.

Obs.: See the reference mark between water pump and block.

Tighten

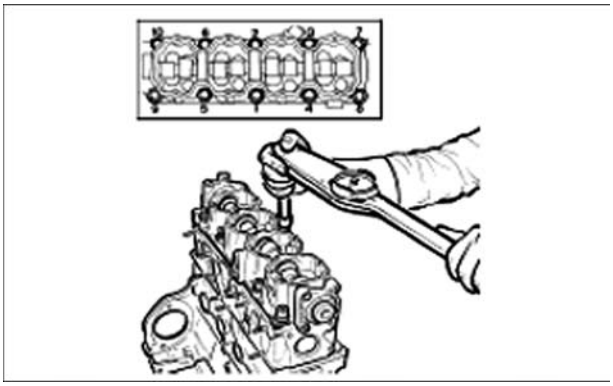
- Bolts: 20 – 30 N·m (14,7 – 22 lb·ft.)

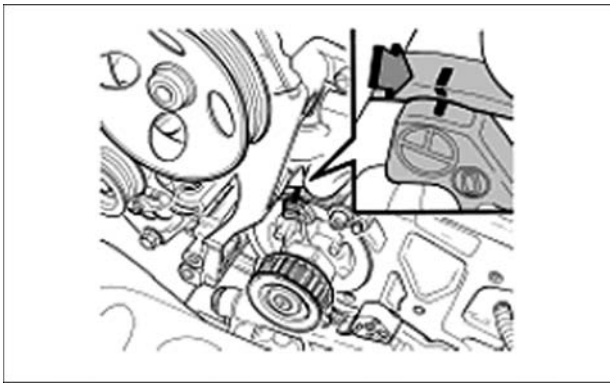
25. New seal ring in the thermostat housing.

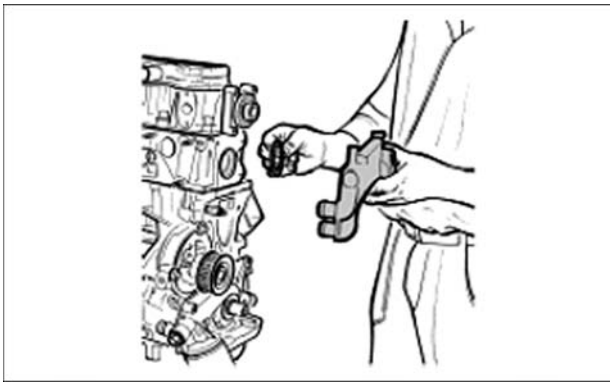
26. Thermostat housing in the cylinder block and its attaching bolts, with a 13-mm socket wrench and torque wrench.

Tighten

- Bolts: 10 – 20 N·m (7 – 15 lb·ft.).







27. Belt rear cover and bolts and attaching nut, with a 10-mm socket wrench and torque wrench.

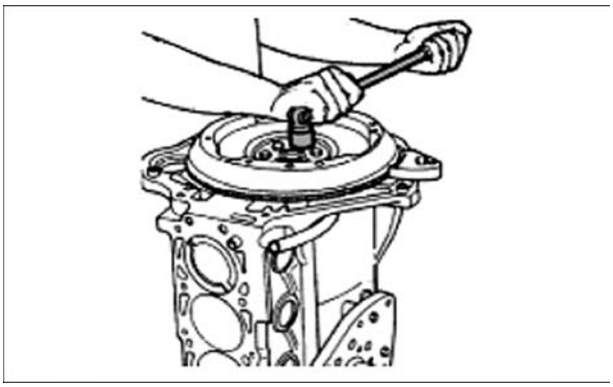
Tighten

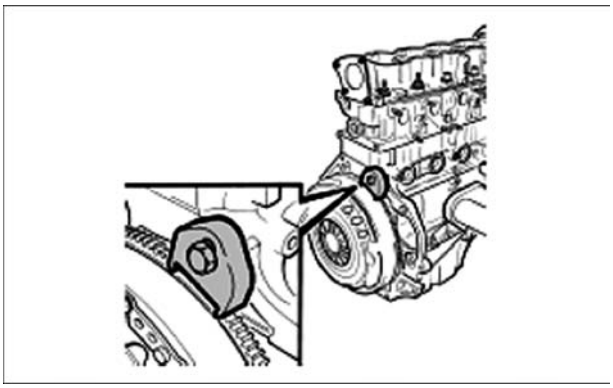
- Bolts: 6 – 10 N·m (4.4 – 7 lb·ft.).
- Nut: 6 – 8 N·m (4.4 – 5.8 lb·ft.).

28. Flywheel and bolts, without giving the final tightening; use a 17-mm socket wrench and handle.

Obs.: Use new bolts.

29. Lock the flywheel with tool S-9407182.





30. Tighten the flywheel bolts, with a 17-mm socket wrench and torque wrench.

Tighten

- Bolts: 35 N·m (26 lb·ft.) + 30° + 15°.

31. Thrust washer in the crankshaft.

32. Thrust key in the crankshaft.

33. Timing pulley, thrust washer and attaching bolt, with a 17-mm socket wrench and torque wrench.

Tighten

- Bolt: 135 N·m (99 lb·ft.) + 30° + 15°.

34. Remove tool S-9406182 from the flywheel with a 17-mm combination wrench.

35. Belt expander with attaching bolt, without tightening.

36. Camshaft timing pulley and attaching bolt, with a 22-mm wrench to lock the camshaft and a 17-mm socket wrench with torque wrench.

Tighten

- Bolt: 40 – 50 N·m (30 – 37 lb·ft.).

37. Camshaft cover and attaching bolts, with a 10-mm socket wrench and torque wrench.

Tighten

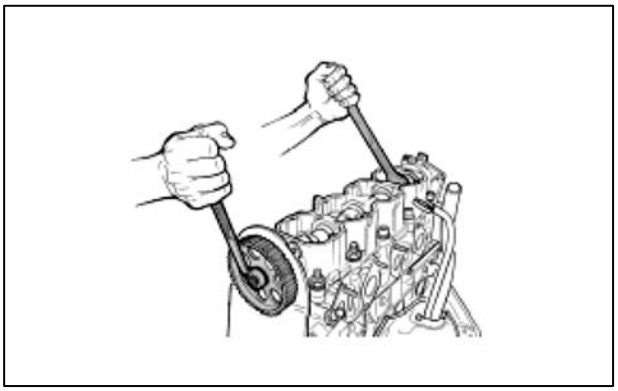
- Bolt: 4 – 10 N·m (3 – 7 lb·ft.).

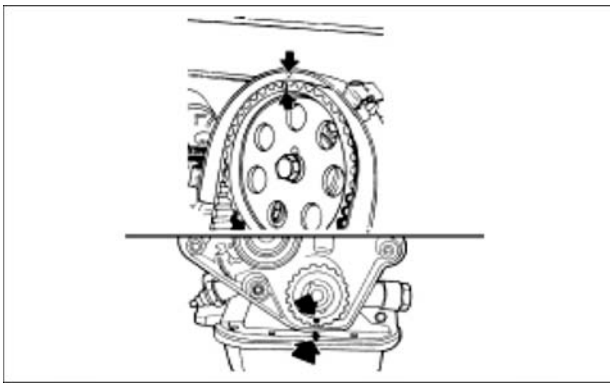
38. Timing pulley.

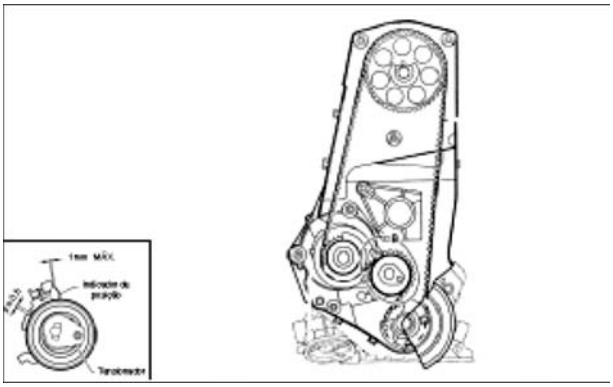
Important

- Timing pulley, keeping stretched the side opposite to the water pump, observing the engine RPM direction, if using the same belt.
- Align the camshaft timing pulley mark with the timing pulley rear cover mark.
- Align the crankshaft timing pulley mark with the oil pump case flange mark, on the no. 1 cylinder combustion stroke.
- Adjust the belt Tensioner; with a 6-mm Allen wrench, so as to keep steady the Tensioner shaft, loosen the Tensioner shaft attaching bolt, use a 13-mm combination wrench until it remains steady. With a 6-mm Allen wrench, turn counterclockwise the Tensioner shaft up to the NEW marking point (± 1 mm) (detail B). The needle can move from the right side up to the final adjusting position. Tighten the bolt with a 13-mm combination wrench; for old timing belts, follow the same procedure, but adjusting the belt in the “USED” position.

  We recommend this change to the used belt, which presents a different operation regarding a new one.







39. Timing pulley front cover and attaching bolts, with a 10-mm socket wrench and torque wrench.

Tighten

- Bolts: 6 – 8 N·m (4.4 – 5.8 lb·ft.).

40. A new gasket in the intake manifold.

41. Intake manifold in the cylinder head and attaching nuts, with a 13-mm socket wrench, extension and torque wrench.

Tighten

- Nuts: 18 – 22 N·m (13 – 16 lb·ft.).

42. A new gasket in the exhaust manifold.

43. Exhaust manifold in the cylinder head and attaching nuts, with a 13-mm socket wrench and torque wrench.

Tighten

- Nuts: 18 – 22 N·m (13 – 16 lb·ft.).

44. A new “O” ring in the crankcase breather tube.

45. Crankcase breather tube and dipstick oil tube in the cylinder block and attaching bolts, with a 13-mm socket wrench and torque wrench.

Tighten

- Bolts: 20 – 30 N·m (15 – 22 lb·ft.).

46. Crankcase breather tube hose to the valve cover, with clamp pliers; attach the same.

47. A new phase and reference sensor seal ring in the crankshaft.

48. Crankshaft position sensor in the cylinder block together with its attaching bolts, with a Torx Bit E10 wrench and torque wrench; tighten.

Tighten

- Bolt: 4 – 8 N·m (3 – 5.8 lb·ft.).

49. Spark plugs, with a spark plug wrench.

50. Power steering pump and attaching bolts, with a 13-mm socket wrench and torque wrench; tighten

Tighten

- Bolts: 20 – 30 N·m (15 – 22 lb·ft.)

51. Generator and attaching bolts, with a 14-mm socket wrench and torque wrench; tighten.

Tighten

- Bolts: 20 – 30 N·m (15 – 22 lb·ft.).

52. Belt automatic tensioner and attaching bolt, with a 16-mm socket wrench and torque wrench; tighten.

Tighten

- Bolt: 18 – 22 N·m (13 – 16 lb·ft.) 53. Clutch; see “Clutch – Installation”, Section 7C.

54. Engine assembly; see “Engine Assembly – Installation”, in this section.

Cylinder Block

Removal

Remove or disconnect

1. Disassemble the engine as per instructions under “Engine Disassembly”, in this section.

2. Water and oil gallery bolts, with a 7-mm Allen wrench and handle.

3. Cylinder block seals.

Clean

- Cylinder block, thoroughly.

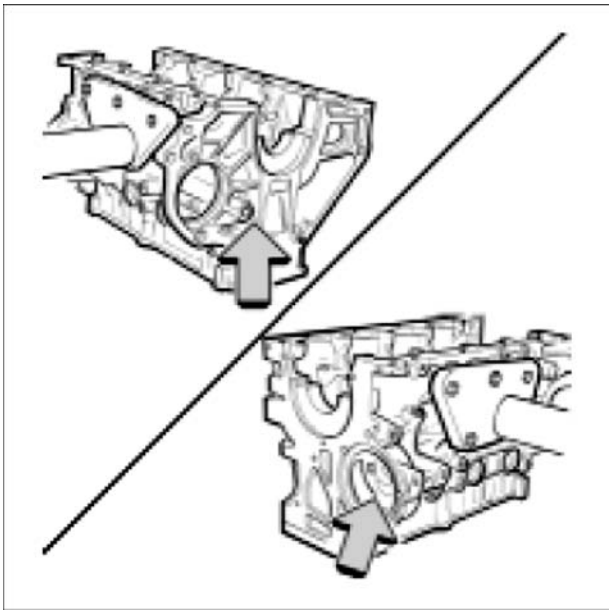
Inspect

- Cylinder block for cracks and wear.

Cylinder Reconditioning

If the cylinder block inspection discloses that only the cylinder are out of roundness and that the cylinder block may be reused, the cylinders can be reconditioned by honing or by grinding or honing or reboring.

If the wear or out-of-roundness is over 0.127 mm (0.005 in.), the cylinders should be rebored and honed until it is possible to install an oversize piston after the reconditioning is finished.



Cylinder Honing

Note: Some of the services that are next presented are not necessarily performed when reconditioning an engine.
The performance should depend on the inspections to which the engines will be submitted before reconditioning.

The finish after reboring should be made with a cylinder hone. The initial honing should be performed with thick stones and finish with thin stones. It should not remain glistened, but with light strokes, so as to help the lubrication.

Install the cylinder hone and lean the stones the maximum as possible, so that the hone does not remain blocked from being manually turned. Connect a 19 mm (3/4 in.) electric driller to the hone, make it rotate and, at the same time, slowly actuate the hone upward and downward, all along the cylinder length, until it freely turns.

When honing, insert into the cylinder a good amount of kerosene, so as to keep the stones and cylinders clean and lubricated.

Expand the hone stones and repeat the honing until obtaining the required diameter.

Note: Stop once in a while the honing and insert the piston into the corresponding cylinder, so as to check the play. Before inserting the piston, thoroughly clean the cylinder.

After servicing the block, clean it thoroughly.

Install or connect

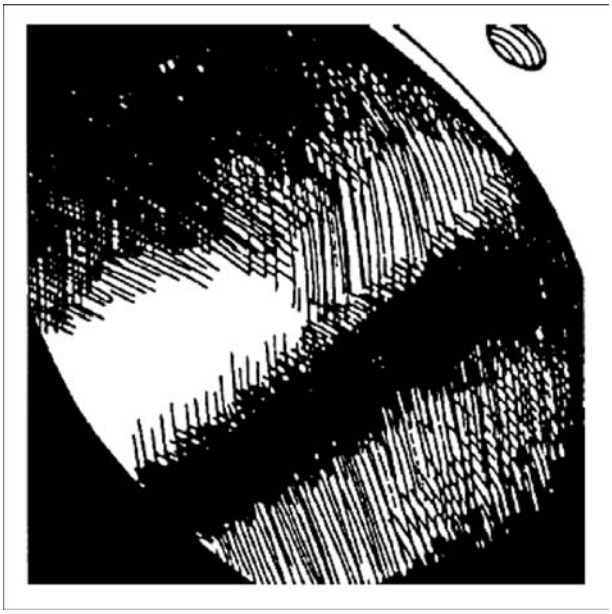
1. Water and oil gallery bolts, with a 7-mm Allen wrench and torque wrench; tighten.

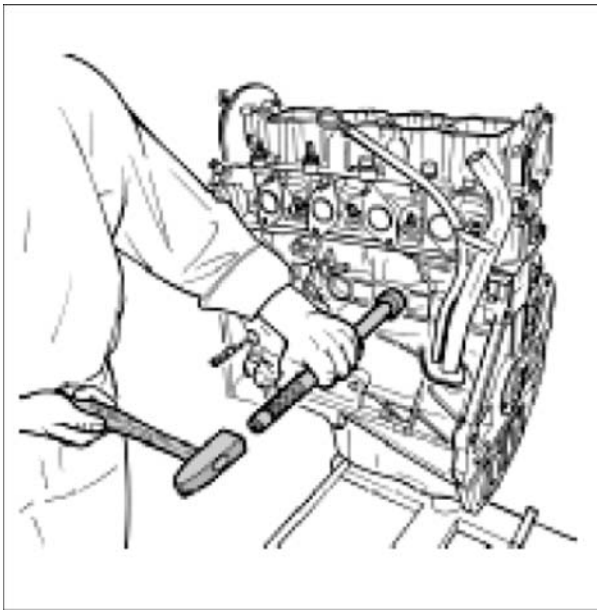
Tighten

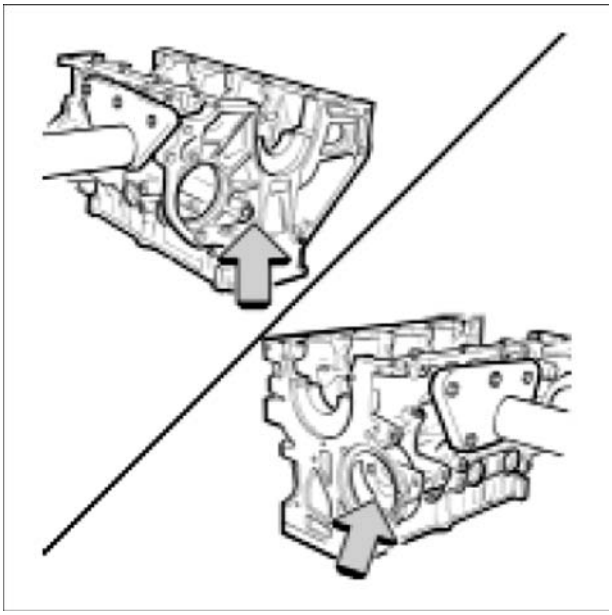
- Bolts: 25 – 35 N·m (18 – 25,7 lb·ft.).

2. Cylinder block seals, with tool 3-0006774 and universal handle M-740463A.

3. Assemble the engine, as per instructions under “Engine Assembly”, in this section.







Crankshaft

Removal

Remove or disconnect

1. Engine assembly, as per instructions under "Engine and Transmission Assembly – Removal", in this section.

2. Install the engine on the engine stand.

3. Disassemble the engine as per instructions under "Engine Disassembly", in this section.

Clean

- Parts and dry with blown air.

Inspect

- Crankshaft saddles for scratches, roughness or other abnormalities.

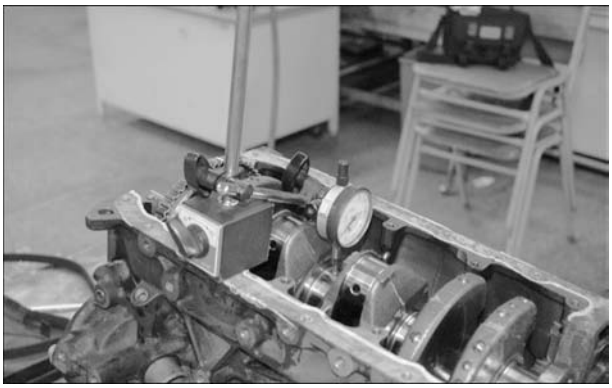
Measure

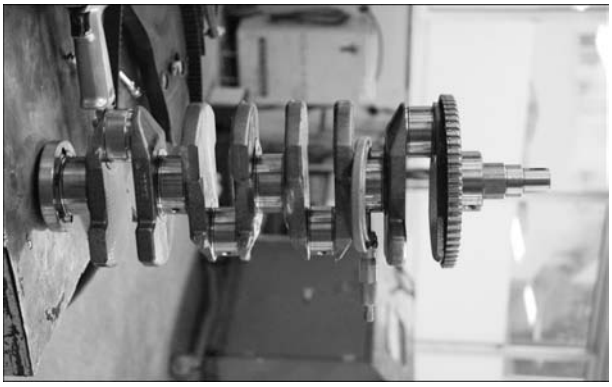
Crankshaft warping, as follows:

- Support the crankshaft by bearings 1 and 5 of the cylinder block, leaving the shells only over these 2 bearings.

- On bearing 3, support the probe of a dial gauge. The total reading indicated on a 360° turn can be 0.003 mm, at the maximum.

- Note the trunnions and journals maximum concentricity, which could be 0.005 mm.
- Note the maximum out-of-rounds, which could be 0.004 mm.
- Note the trunnions and journals diameter and check in the shell table that should be used. If the diameters are not between those indicated in the table, the crankshaft should be rebored or replaced.





Important

- If necessary to determine the saddle-to-shell play, use Plastigage.
- If Plastigage is not available, remove the crankshaft, install the bearing cap with shells and bolts and tighten to the specification. Measure the shell inner bore and saddle diameter corresponding to the bearing in the crankshaft.





Installation

Install or connect

1. Upper shells in the block; lubricate the surface turned toward the saddle with engine oil.

2. Crankshaft.

3. Main bearing caps with the shells lubricated on the surfaces turned toward the saddle.

Important

- The bearing caps should be installed so that the cast numbers base (1) stays turned toward the engine rear side. Pay attention also to the sequential engraved numbers.
- Fill the rear bearing cap side grooves with sealant.

4. Main bearing attaching bolts, without tightening.

Important

- With a plastic mallet, slightly tap the crankshaft, in two directions, so as to mainly seat the thrust bearing rear face.

5. Tighten the main bearing attaching bolts, with a Torx E12 wrench, extension and torque wrench.

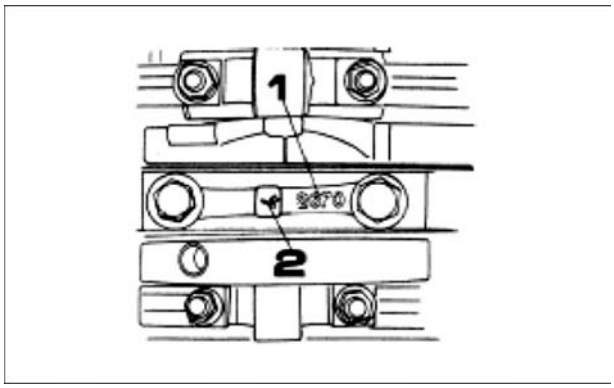
Tighten

- Bolts: 50 N·m + 45° + 15°.

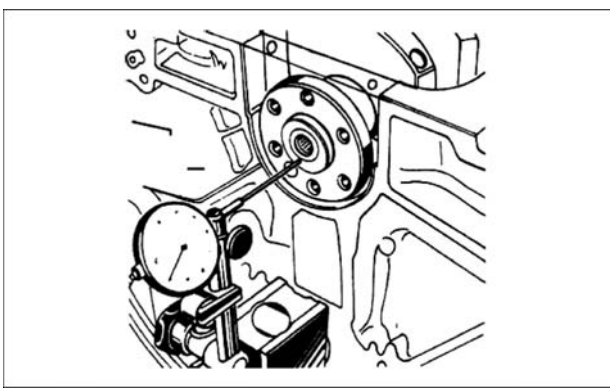
Measure

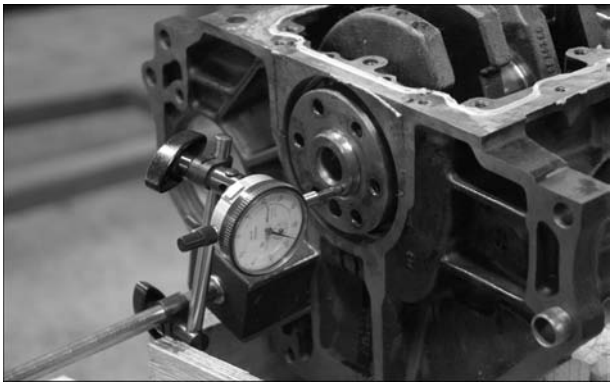
Crankshaft end clearance, as follows:

- Install a dial gauge so that the probe touches the crankshaft end.
- With the aid of a screwdriver, displace the crankshaft to and fro and read the dial gauge
- The specified clearance is .....0.070 – 0.302 mm (0.003 – 0.012 in.).



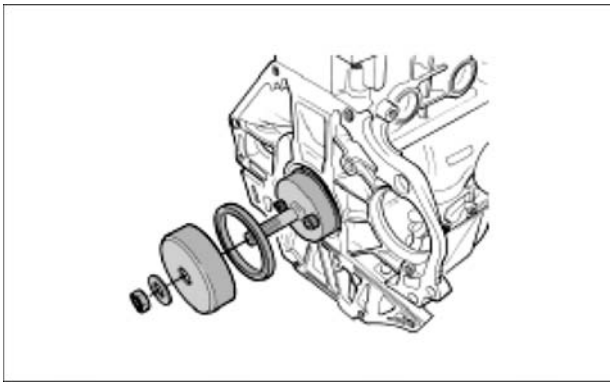


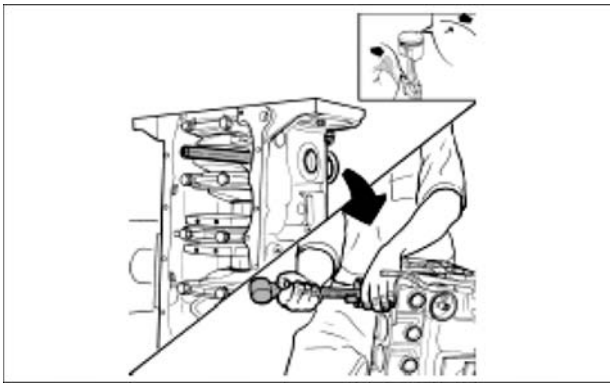




6. A new seal in the crankshaft, with tool KM-658.

7. Piston-connecting rod assembly with the aid of the universal band, positioning the piston arrow turned toward the engine front end.





Important

- Lubricate the rings and cylinders.
- Simultaneously, guide the connecting rod bearing with tool T-9806681.
- Install the connecting rod upper shell, lubricated only in the face turned to the journal, and pull the connecting rod until it touches the journal.

8. Connecting rod cap, with the lower shell lubricated only in the face turned to the journal.

9. Connecting rod cap bolts, without fully tightening, with a 14-mm socket wrench and handle.

Important

- Rotate the crankshaft some turns, so that the connecting rods are properly seated.

10. Tighten the connecting rod cap bolts, with a 14-mm socket wrench and torque wrench.

Tighten

- Connecting rod cap bolts: .....30 – 40 N·m (22.0 – 29.5 lb·ft.) + 40° to 45°.

11. A new gasket in the oil pump.

12. Oil pump to cylinder block and attaching bolts, with a 5-mm Allen wrench and torque wrench.

Tighten

- Bolts: 4 – 10 N·m (3 – 7 lb·ft.).

13. Balancer and baffle plate and attaching bolts, with a Torx E12 wrench and torque wrench.

Tighten

- Bolts: 20 – 24 N·m (15 – 17.6 lb·ft.).

Obs.: One of the bolts only can be installed and tightened after installing the oil strainer.

14. Oil strainer and attaching bolts in the oil pump, with a 10-mm socket wrench and torque wrench; tighten.

Tighten

- Bolt: 4 – 10 N·m (3 – 7 lb·ft.).

15. Adhesive sealant in the cylinder block and install the crankcase and attaching bolts; tighten with a Torx E12 wrench and torque wrench.

Tighten

- Bolts: 6 – 10 N·m (4.5 – 7 lb·ft.).

16. Oil filter.

Obs.: Only tighten with your hands.

17. Turn tool M-780668 180°, so that the engine stay with the pistons turned upward.

18. A new cylinder head gasket, with the TOP mark turned upward and toward the engine front side.

Obs.: Whenever is necessary to remove the cylinder head, a new gasket should be used.

19. Cylinder head in the engine.

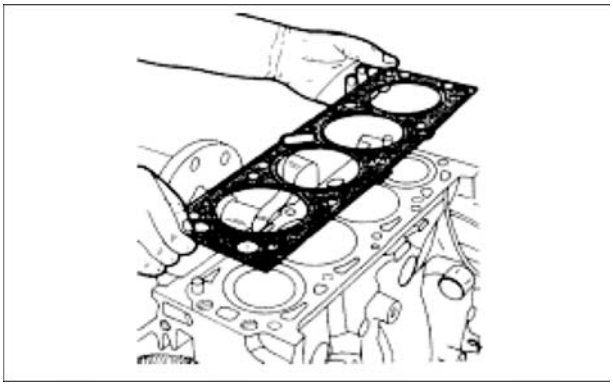
20. Valve lifters, linkages and rocker arms, lubricated with molybdenum bisulfate compound.

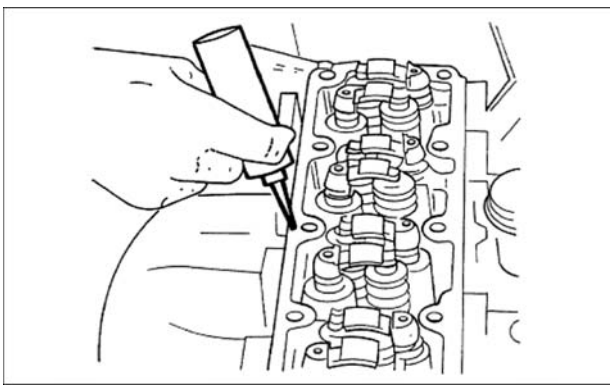
Important

- Apply sealing compound in the surface where the camshaft case will be seated.

21. Camshaft case.







22. New cylinder head attaching bolts, in the indicated sequence, with a Torx E55 wrench and torque wrench.

Tighten

- Bolts: 25 N·m (18 lb·ft.) + 180° + 10°.

23. A new “O” ring in the water pump.

24. Water pump and attaching bolts, with a 6-mm Allen wrench and torque wrench.

Tighten

- Bolts: 20 – 30 N·m (14,7 – 22 lb·ft.).

25. A new “O” ring in the thermostat housing.

26. Thermostat housing in the cylinder block and attaching bolts, with a 13-mm socket wrench and torque wrench.

Tighten
- Bolts: 10 – 20 N·m (7 – 15 lb·ft.).

27. Belt rear cover and bolts and one attaching nut, with a 10-mm wrench and torque wrench.

Tighten

- Bolts: 6 – 10 N·m (4.4 – 7 lb·ft.).

- Nut: 6 – 8 N·m (4.4 – 5.8 lb·ft.).

28. Flywheel and bolts, without tightening; use a 17-mm wrench and handle.

Obs.: Use new bolts.

29. Attach the flywheel with tool S-9407182.
30. Tighten the flywheel bolts with a 17-mm socket wrench and torque wrench.

Tighten

- Bolts: 35 N·m (26 lb·ft.) + 30° + 15°.

31. Thrust washer in the crankshaft.

32. Thrust key in the crankshaft.

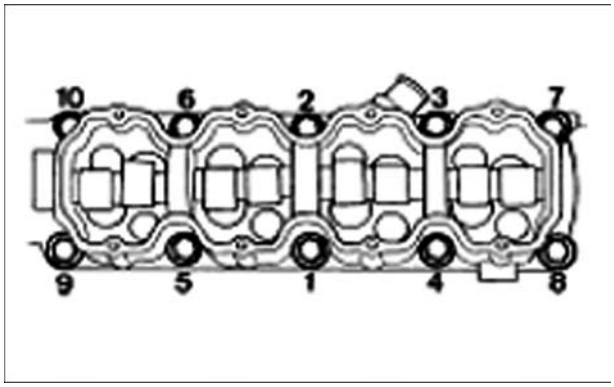
33. Timing pulley, thrust washer and attaching bolt, with a 17-mm socket wrench and torque wrench.

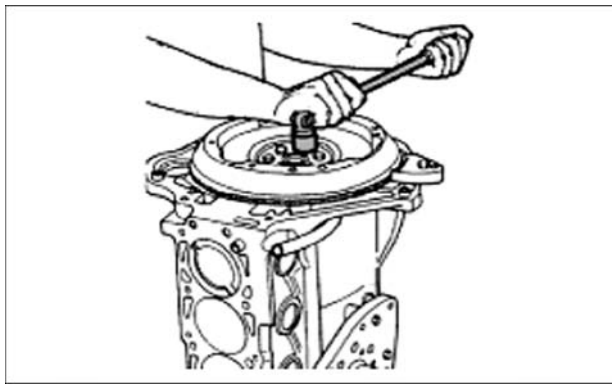
Tighten

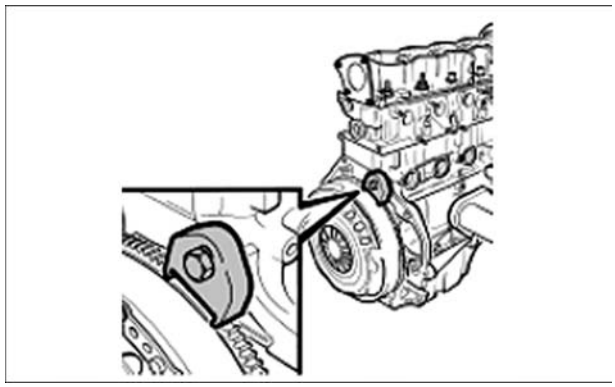
- Bolt: 40 – 50 N·m (30 – 37 lb·ft.).

34. Remove tool S-9406182 from the flywheel with a 17-mm combination wrench.

35. Belt expander with attaching bolt, without tightening.







36. Camshaft timing pulley and attaching bolt, with a 22-mm box-end wrench to lock the camshaft and a 17-mm socket wrench and torque wrench.

Tighten

- Bolt: 40 – 50 N·m (30 – 77 lb·ft.).

37. Camshaft cover and attaching bolts, with a 10-mm socket wrench and torque wrench; tighten.

Tighten

- Bolts: 4 – 10 N·m (3 – 7 lb·ft.).

38. Timing belt.

Important

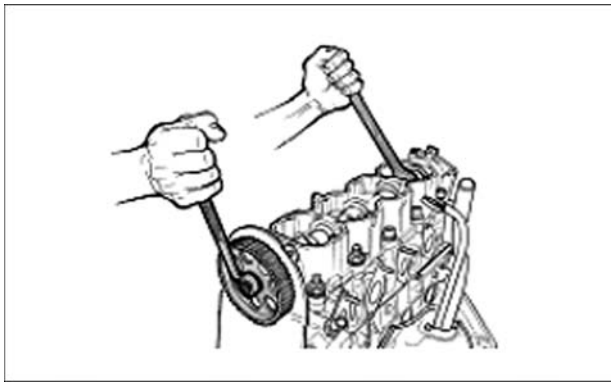
- Timing pulley, keeping stretched the side opposite to the water pump, observing the engine RPM direction, if using the same belt.
- Align the camshaft timing pulley mark with the timing pulley rear cover mark.
- Align the crankshaft timing pulley mark with the oil pump case flange mark, on the no. 1 cylinder combustion stroke.
- Adjust the belt Tensioner; with a 6-mm Allen wrench, so as to keep steady the Tensioner shaft, loosen the Tensioner shaft attaching bolt, use a 13-mm combination wrench until it remains steady.

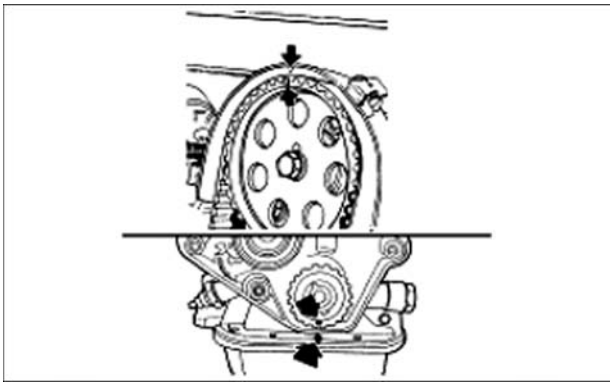
With a 6-mm Allen wrench, turn counterclockwise the Tensioner shaft up to the NEW marking point (± 1 mm) (detail B). The needle can move from the right side up to the final adjusting position. Tighten the bolt with a 13-mm combination wrench; for old timing belts, follow the same procedure, but adjusting the belt in the “USED” position.
This change is suggested due to the old belt presenting a different course of action regarding the new belt.

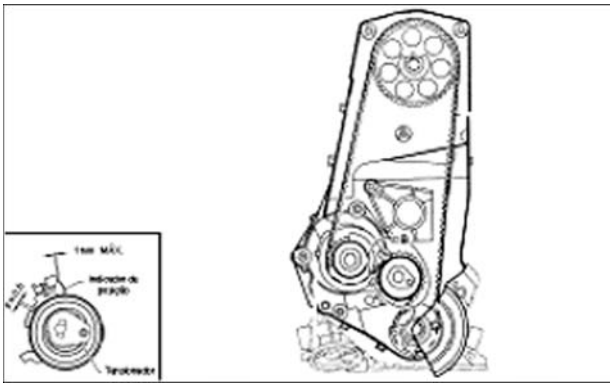
39. Timing belt front cover and attaching bolts, with a 10-mm socket wrench and torque wrench.

Tighten

- Bolts: 6 – 8 N·m (4.4 – 5.8 lb·ft.).







40. A new gasket in the intake manifold.

41. Intake manifold in the cylinder head and attaching nuts, with a 13-mm socket wrench, extension and torque wrench.

Tighten

- Nuts: 18 – 22 N·m (13 – 16 lb·ft.).

42. A new gasket in the exhaust manifold.

43. Exhaust manifold in the cylinder head and attaching nuts; use a 13-mm socket wrench, extension and torque wrench.

Tighten

- Nuts: 18 – 22 N·m (13 – 16 lb·ft.)

44. A new “O” rings in the crankcase breather tube.

45. Crankcase breather tube and oil dipstick tube in the cylinder block and attaching bolts, with a 13-mm socket wrench and torque wrench.

Tighten

- Bolts: 20 – 30 N·m (15 – 22 lb·ft.).

46. Crankcase breather tube-to-valve covers hose, with clamp pliers; attach the same.

47. A new seal ring in the crankcase phase and reference sensor.

48. Crankshaft phase and reference sensor in the cylinder block and attaching bolt; use a Torx E10 wrench and torque wrench to tighten.

Tighten

- Bolt: 4 – 8 N·m (3 – 5.8 lb·ft.).

49. Spark plugs, with a proper wrench
.

50. Power steering pump and attaching bolts, with a 13-mm socket wrench and torque wrench.

Tighten

- Bolts: 20 – 30 N·m (15 – 22 lb·ft.).

51. Generator and attaching bolts, with a 14-mm socket wrench and torque wrench; tighten.

Tighten

- Bolts: 20 – 30 N·m (15 – 22 lb·ft.).

52. Belt automatic tensioner with attaching bolt, with a 16-mm socket wrench and torque wrench; tighten.

Tighten

- Bolt: 18 – 22 N·m (13 – 16 lb·ft.).

53. Clutch; see “Clutch – Installation”, section 7C.

54. Engine assembly; see “Engine Assembly – Installation”, in this section.

Pistons and/or Connecting Rods

Removal

Remove or disconnect

1. Engine and transmission assembly, as per instructions under “Engine and Transmission Assembly – Removal”, in this section.

2. Clutch; see “Clutch – Removal”, on Section 7C.

3. Power steering pump attaching bolts, with a 13-mm box-end wrench; remove the pump.

4. Generator attaching bolt, with a 14-mm box-end wrench; remove the generator.

5. Cylinder head; see “Cylinder Head – Removal”, in this section.

6. Turn the engine 180° to have access to the engine crankcase.

7. Engine crankcase attaching bolts, with a Torx E12 wrench, extension and handle; remove the crankcase from the engine.

8. Oil strainer attaching bolt, with a 10-mm socket wrench and handle. Remove the oil strainer bolts and Torx E12 wrench. Loosen the attaching bolt from the oil strainer stem.

9. Baffle plate and balancer attaching bolts, with a Torx E12 wrench and handle; remove the baffle plate and balancer.

10. Install two flywheel attaching bolts to the crankshaft to rotate the latter and ease the access to the connecting rod attaching bolts.

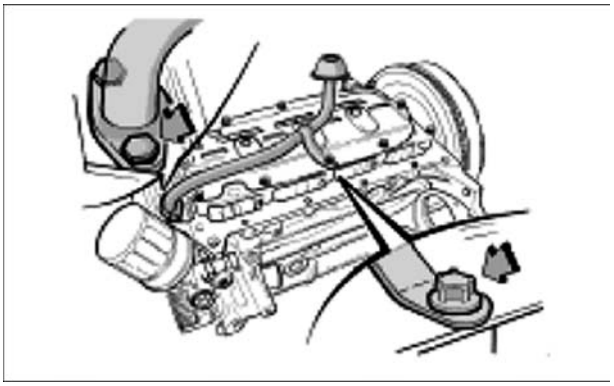
11. With a punch identify the connecting rod bearing and connecting rod, according to the corresponding cylinder.

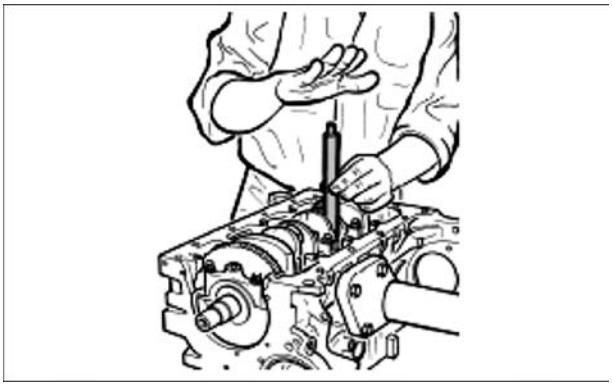
12. Turn the crankshaft until the first and fourth connecting rod remains with the attaching bolts upward.

13. First and fourth connecting rod bearing attaching bolts, with a 14-mm wrench, extension and handle; remove the connecting rod caps.

14. Install tool T-9806681 in the connecting rod and remove the piston.

15. Turn the crankshaft until the second and third connecting rods have the attaching bolt turned upward.





16. Second and third connecting rod bearing attaching bolts, with a 14-mm socket wrench, extension and handle; remove the connecting rod caps.

17. Install tool T-9806661 in the connecting rod and remove the piston.

Measure

- Clearance between pistons and cylinders, which should be 0.010 – 0.030 mm.

Important

- The pistons are available in standard size and 0.50-mm (0.020 in.) oversize.

Inspect

- Pistons for cracked walls, grooves, skirts or supports.
- Waving in the rings fitting.
- Warping, damages or corroded areas in piston head.

Disassemble

1. Piston pin, placing the piston in the support base J-8606014 and using puller T-9806680-1 with universal handle M-840911A and press.

2. Connecting rod in the piston.

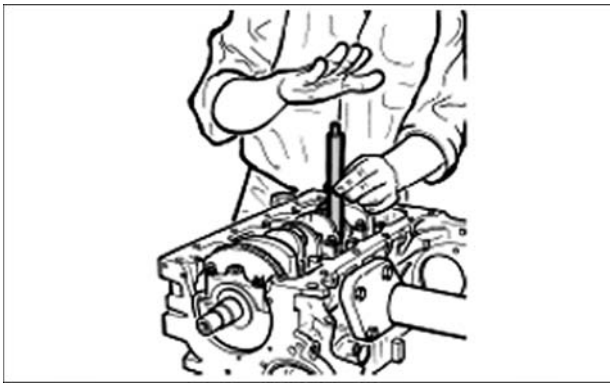
Assemble

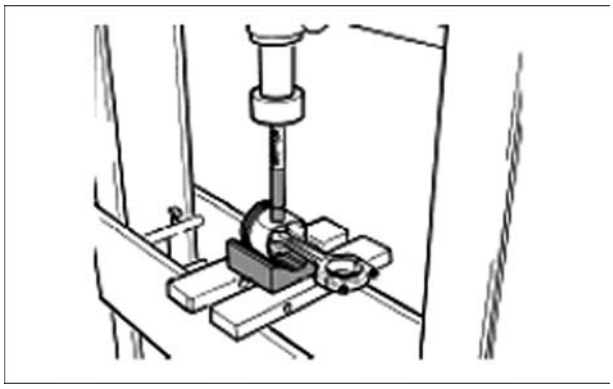
1. Connecting rod in the piston.

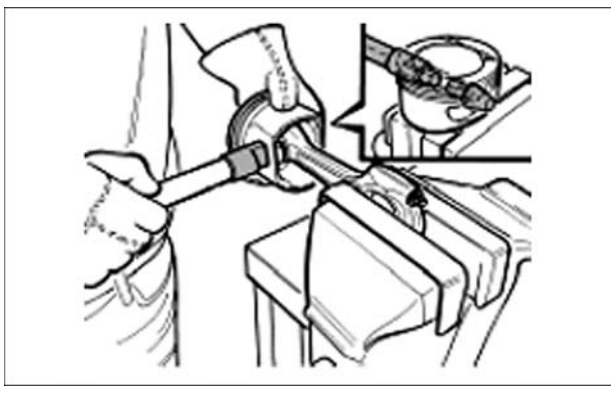
Clean

- The piston varnish; clean the grooves with a proper scraper; unclog the oil grooves and holes.

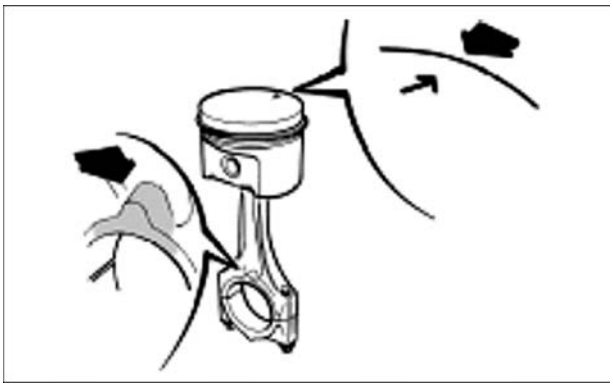
2. Piston pin; for this, proceed as follows:
Warm the connecting rod from 280° C to 320° C, in the piston pin hole area. The heating should be made preferably in oil bath. Cool the pin with dry ice.
Attach the warmed connecting rod in the vise, this with aluminum jaws.
By keeping the piston touching the connecting rod face, on the side where the pin is to be assembled, insert it into its lodgment with the aid of tool T-806680/20, and guide.







Obs.: This procedure should be performed with protecting gloves.
These procedures should be followed so that the connecting rod projection is located opposite the arrow in the piston head.



Rings

Measure

Gap between the tips of the selected ring, according to the piston size; install the ring into the cylinder and push it with a piston so that it stays flush with the cylinder wall.

The gap should be:

- Compression ring: .....0.30 – 0.50 mm (0.012 – 0.020 in.).
- Scrape-type oil control ring: .....0.40 – 1.40 mm (0.016 – 0.055 in.).

Measure

Gap between rings and grooves, which should be:

- Upper compression ring: 0.060 – 0.092 mm.
- Lower compression ring: 0.030 – 0.062 mm.

Installation

Install or connect

1. Rings in the piston, following the installation sequence of the openings and considering that the vertical dash line (C) corresponds to the pin position.

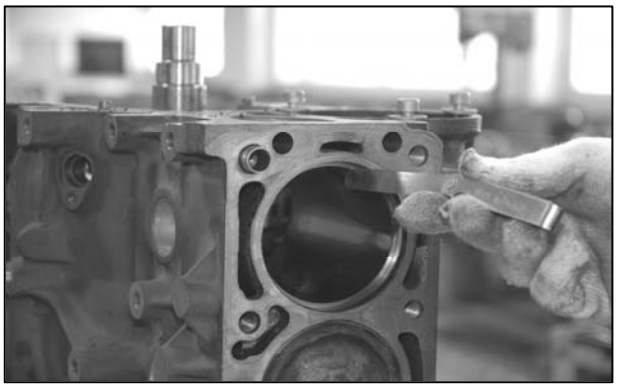
B. Oil control ring.

C. Spacer ring.

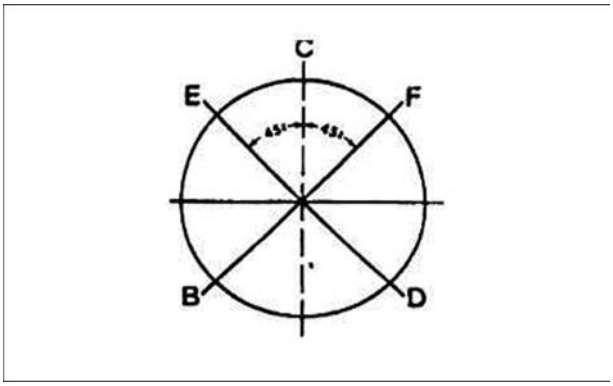
D. Oil control ring.

E. Lower compression ring.

F. Upper compression ring.





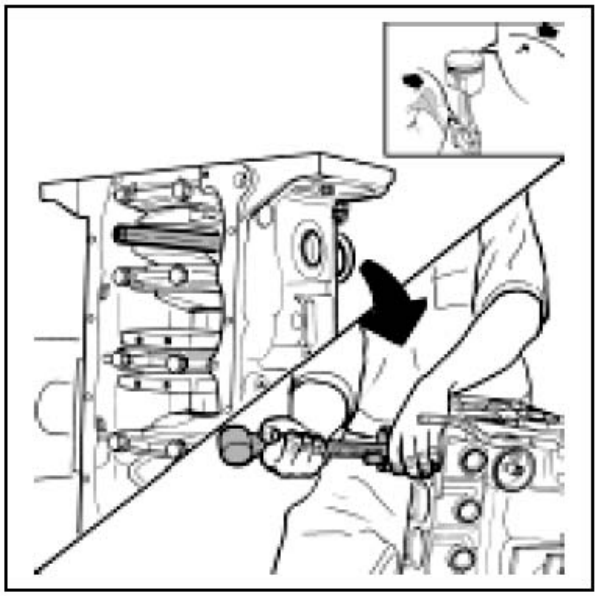


2. Piston-connecting rod assembly in the block, with the aid of the universal band, positioning the piston arrow turned toward the engine front end.

Important

- Lubricate the rings and cylinders.
- Simultaneously, guide the connecting rod bearing with tool T-9806681.

- Install the connecting rod upper shell lubricated only in the face turned toward the journal and pull the connecting rod until it touches the journal.



3. Connecting rod cap, with the lower shell lubricate only in the face turned toward the journal.

4. Connecting rod cap bolts, without fully tightening, with a 14-mm socket wrench and handle.

Important

- Rotate the crankshaft some turns so that the connecting rods are properly seated.

5. Tighten the connecting rod cap attaching bolts with a 14-mm socket and torque wrench.

Tighten

- Connecting rod cap bolts: .....30 – 40 N·m (22 – 29.5 lb·ft.) + 40° to 45°.

6. Balancer and baffle plate and attaching bolts, with a Torx E12 wrench and torque wrench.

Tighten

- Bolts: 20 – 24 N·m (15 – 17.6 lb·ft.).

Obs.: One of the bolts only can be installed and tightened after the installation of the oil strainer.

7. Oil strainer and attaching bolts to the oil pump, with a 10-mm socket wrench and torque wrench; give the final tightening.

Tighten

- Bolt: 4 – 10 N·m (3 – 7 lb·ft.)

8. Adhesive sealant in the cylinder block and install the crankcase and attaching bolts, with a Torx E12 wrench and torque wrench; tighten.

Tighten

- Bolts: 5 – 10 N·m (4.5 – 7 lb·ft.)

9. Turn tool M-780668 180° so that the engine stay with the pistons turned upward.

10. Cylinder head; see “Cylinder Head – Installation”, in this section.

11. A new “O” ring in the crankshaft phase and reference sensor.

12. Crankshaft phase and reference sensor in the cylinder block and attaching bolt, with a Torx E10 wrench and torque wrench; tighten.

Tighten

- Bolt: 4 – 8 N·m (3 – 5.8 lb·ft.)

13. Generator and attaching bolts, with a socket wrench and torque wrench; tighten.

Tighten

- Bolts: 20 – 30 N·m (15 – 22 lb·ft.)

14. Power steering pump and attaching bolts with a 13- mm socket wrench and torque wrench; tighten.

Tighten

- Bolts: 20 – 30 N·m (15 – 22 lb·ft.)

15. Clutch; see “Clutch – Installation”, section 7C.

16. Engine assembly, as per instructions under “Engine Assembly – Installation”, in this section.

Chapter 4. ENGINE ELECTRICAL SYSTEM

Specifications

Ignition Coil

Item	Specification
Primary resistance	0.15Ω
Secondary Load resistance	2,500Ω

Spark Plug

Item	Specification
Spark plug gap	0.7 ~ 0.8mm

Starter Motor

Item	Specification
Output	12V- 1.4 kW
Pinion tooth number	8

Alternator

Item	Specification
Rated output	13.5V - 80A
RPM	1,000 ~ 18,000rpm
Voltage regulator type	Electronic, Built-in type

Ignition System

Spark-ignited engines require accurate control of spark timing and spark energy for efficient combustion. The MI-07 ignition system provides this control. The system consists of the following components:

- SECM
- Ignition coil drivers *
- Ignition coil(s) *
- Crankshaft position sensor *
- Crankshaft timing wheel *
- Cam position sensor *
  (for sequential ignition or fuel injection only)
- Cam timing wheel *
  (for sequential ignition or fuel injection only)
- Spark plugs *

The SECM, through use of embedded control algorithms and calibration variables, determines the proper time to start energizing the coil and fire the spark plug. This requires accurate crank/camshaft position information, an engine speed calculation, coil energy information, and target spark timing. The SECM provides a TTL compatible signal for spark control. The coil must contain the driver circuitry necessary to energize the primary spark coil otherwise an intermediary coil driver device must be provided. The SECM controls spark energy (dwell time) and spark discharge timing.

Wasted Spark DIS Ignition System

The G424F and G424FE engine has a wasted spark ignition system (2 cylinders per coil).

Wasted spark ignition is a type of distributor-less ignition system where a pair of multi tower coils is mounted near the spark plugs. The DIS system eliminates the wear associated with most distributor type ignition systems. The wasted spark ignition fires pairs of cylinders at each ignition event. One cylinder fires on the compression stroke as is normal. However, the complementary pair in the firing order is fired simultaneously while that particular cylinder is on the exhaust stroke. Since the ionized exhaust gases require little spark energy, the majority of the ignition energy from the coil goes to the spark plug in the cylinder on the compression stroke.

The DIS coil pack can be mounted close to the spark plugs, thereby improving ignition lead routing and length. There are fewer parts to malfunction on the DIS system when compared to a distributor type system.

DIS COMPONENTS

In a typical DIS ignition system, a crankshaft position sensor generates a basic timing signal by reading notches on the crankshaft, flywheel, or harmonic balancer. The crank sensor signal goes to the small engine control module (SECM), where it is used to determine firing order and turn the individual ignition coils on and off.

The operation of the ignition system is essentially the same as any other ignition system. Each coil has a low primary resistance (0.4 to 0.6 ohms) and steps up the primary system voltage from 12 volts to as much as 40,000 volts to produce a spark for the spark plug.

It is a direct connection that delivers the hottest spark possible. Resistor plugs are generally used to suppress electromagnetic interference (EMI).

MISFIRES

DIS problems can include many of the same ailments as other ignition systems such as misfiring, hard starting, or a no start. Spark plugs can still be fouled by oil or fuel deposits, as well as pre-ignition and detonation.

If the crankshaft position sensor fails, the loss of the basic timing signal will prevent the system from generating a spark and the engine will not start or run. A failed driver circuit within the SECM can kill individual coils and prevent two cylinders from firing.

It is important to remember that ignition misfire can also be caused by other factors such as worn or fouled spark plugs, loose or damaged coil connector or terminals, dirty fuel injectors, low fuel pressure, intake vacuum leaks, loss of compression in a cylinder, even contaminated fuel. These other possibilities should all be ruled out before a DIS unit is replaced.

A DIS engine that cranks but fails to start, in many cases, will often have a problem in the crankshaft or camshaft position sensor circuits. Loss of sensor signals may prevent the SECM from properly synchronizing, thereby preventing the engine from starting and running.

DIS CHECKS

Individual ignition coils can be tested with an ohmmeter the same as those on a conventional distributor system. Measure primary and secondary resistance and compare to specifications. If resistance is out of specifications, the coil is bad and needs to be replaced.

Also, pay close attention to the tube that wraps around the spark pug. Cracks can allow voltage to jump to ground causing a misfire. The spark plug terminal should also fit tightly.

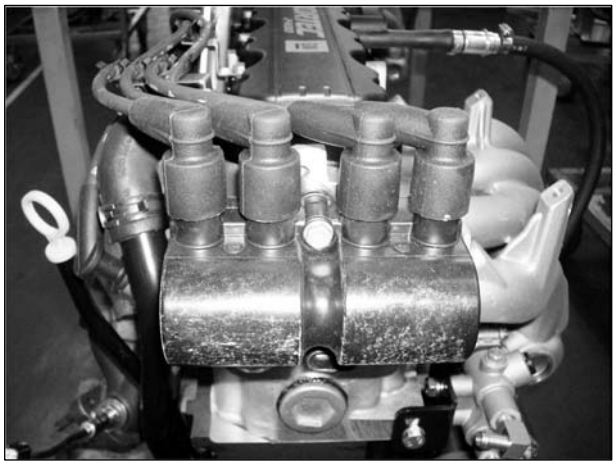
If a coil tests bad and is replaced, cleaning the connector and wiring harness terminals can often avoid future problems. Corrosion at either place can cause intermittent operation and loss of continuity, which may contribute to component failure. Applying dielectric grease to these connections can help prevent corrosion and assure a good electrical connection.

Magnetic crankshaft position sensors can be tested with an ohmmeter, and the sensor output voltage and waveform can be read with an oscilloscope. The output voltage of a Hall Effect crankshaft position sensor can be checked with a voltmeter. On most vehicles, a defective crank position sensor will usually set a fault code that can be read with the Service Tool.

Inspection of Ignition Coil

The operation of the ignition system is essentially the same as any other ignition system. Each coil has a low primary resistance (0.4 to 0.6 ohms) and steps up the primary system voltage from 12 volts to as much as 40,000 volts to produce a spark for the spark plug.

It is a direct connection that delivers the hottest spark possible. Resistor plugs are generally used to suppress electromagnetic interference (EMI).



Terminal A : EST 2 (Fires 2 & 3)
Terminal B : EST 1 (Fires 1& 4)
Terminal C : Ground
Terminal D : B+

Primary Resistance: 0.15 ohms
Secondary Load Resistance: 2,500 ohms

Spark Plug Wire Inspection

Sparking plug wire integrity is vital for proper engine operation. A Thorough inspection will be necessary to accurately identify conditions that may affect engine operation. Inspect for the following condition:

1. Correct routing of the spark plug wires. Incorrect routing may cause cross-firing

2. Any signs of cracks or splits in the wires

3. Inspect each boot for the following conditions:
- Tearing
- Piercing
- Arcing
- Carbon tracking
- Corroded terminal

If corrosion, carbon tracking, or arcing is indicated on a spark plug boot or on a terminal, replace the wire and the component connected to the wire.

Spark Plug Wire Replacement

Removal

Remove or disconnect

1. Disconnect the spark plug wire at each spark plug. See Figure 81

a. Twist the boots 1/2 turn before removing the boots

b. Pull only on the boot or use a tool designed for this purpose in order to remove the wire from each spark plug.



2. Disconnect the spark plug wire from the coil pack.

a. Twist each spark plug boot 1/2 turn.

b. Pull only on the boot or use a tool designed for this purpose in order to remove the wires from the coil pack.

Installation

Install or connect

Note: If the boot-to-wire movement has occurred, the boot will give a false visual impression of being fully seated. Ensure that the boots have been properly assembled by pushing sideway on the installed boots. Failure to properly seat the terminal onto the spark plug will lead to wire core erosion an result in an engine misfire or crossfire condition and possible internal damage to the engine.

1. Install the spark plug wires at the coil pack. You should feel the terminal snap onto the coil.

2. Install the spark plug wire to each spark plug. You should feel the terminal snap onto the spark plug. See Figure 81.

3. Inspect the wires for proper installation:

a. Push sideways on each boot in order to inspect the seating.

b. Reinstall any loose boot. You should feel the terminal snap onto the spark plug or coil when installing the spark plug wire. Inspect and replace component that is damaged

c. Wire routing must be kept intact during service and followed exactly when wires have been disconnected or when replacement of the wires is necessary. Failure to route the wires properly can lead to radio ignition noise and cross firing of the plugs or shorting of the leads to the ground.

d. Any time the spark plug wires or boots are installed on the spark plug, new dielectric grease needs to be applied inside the boot.

Spark Plug Replacement

Removal

Remove or disconnect

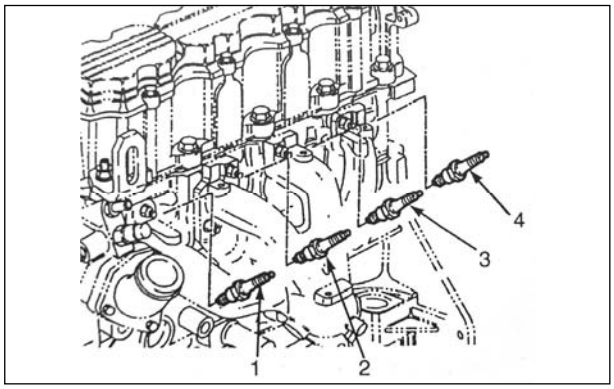
1. Remove the spark plug wires. Refer to spark Plug Wire Replacement.

2. Loosen each spark plug 1 or 2 turns.

3. Brush or air blast away any dirt form around the spark plugs.

4. Remove the spark plugs 1 at a time. Place each plug in a tray marked with the corresponding cylinder number. See Figure 82.

5. Inspect each spark plug. See Spark Plug Inspection



Installation

Install or connect

1. Properly position each spark plug washer.

2. Inspect each spark plug gap. Adjust each plug as needed.

Specification
Spark plug gap: 0.8 to 0.9 mm (0.031 to 0.035 in.)

3. Head start the spark plugs in the corresponding cylinders. See Figure 82.

⚠ CAUTION

Only use a spark plug socket or wrench to tighten the spark plugs. Do not force the spark plug into the cylinder head. Any misalignment can damage the aluminum threads in the cylinder head and may required the replacement of the cylinder head.

4. Tighten the spark plug to 20 N•m (15 lbf ft)

Spark Plug Inspection

Usage

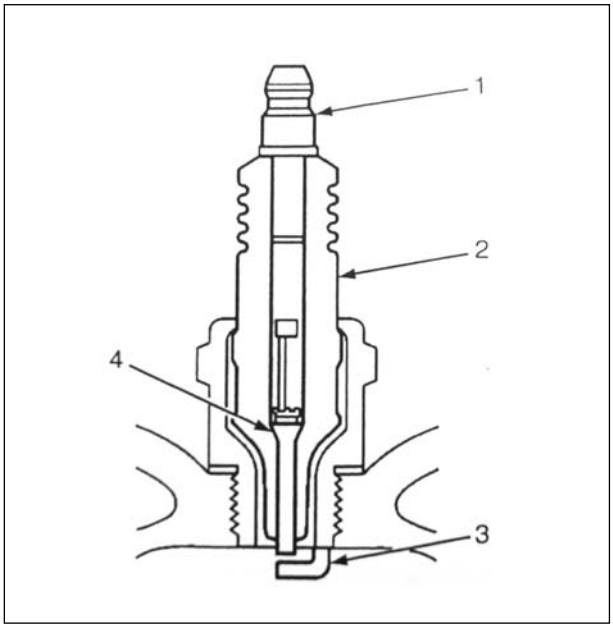
1. Ensure that the correct spark plug is installed. An incorrect spark plug causes driveability conditions.

2. Ensure that the spark plug has the correct heat range. An incorrect heat range the following conditions:
- Spark plug fouling – Colder plug
- Pre-ignition causing spark plug and/or engine damage – Hotter plug

Inspect

1. Inspect the terminal post for damage.

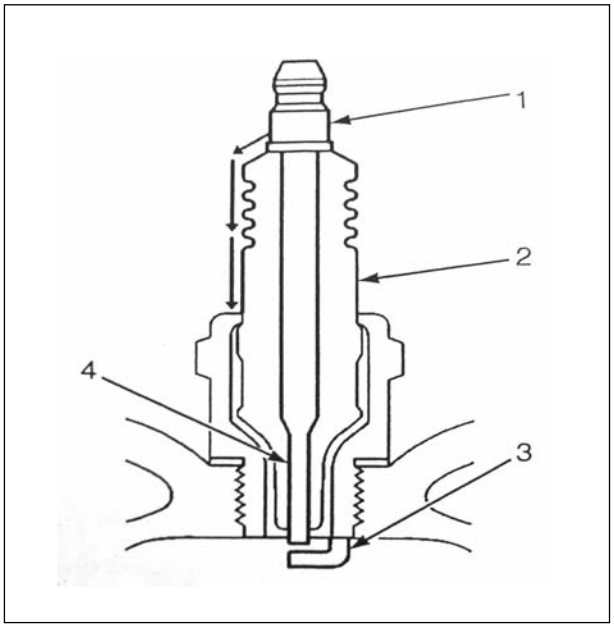
a. Inspect for a bent or broken terminal post.



b. Best for a loose terminal post by twisting and pulling the post. The terminal post should NOT move.

2. Inspect the insulator for flashover or carbon tracking soot. See Figure 84. This is caused by the electrical charge traveling across the insulator between the terminal post and ground. Inspect for the following conditions:

a. Inspect the spark plug boot for damage.



b. Inspect the spark plug recess area of the cylinder head for moisture, such as oil, coolant, or water. A spark plug boot that is saturated causes arcing to ground.

3. Inspect the cylinder for cracks. All or part of the electrical charge may arc through the crack instead of the electrodes. See Figure 85.

4. Inspect for evidence of improper arcing. See Figure 86.

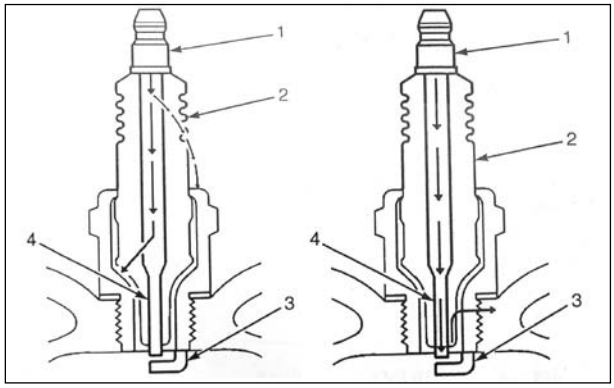
a. Measure the gap between the center electrode (4) and the side electrode (3) terminals. An excessively wide electrode gap can prevent correct spark plug operation. Refer to Engine Speculations for the proper gap. Adjust as necessary.

b. Inspect for the correct spark plug torque. The correct torque is 20 N•m (15 lbf ft). Insufficient torque can prevent correct spark plug operation. An over-torqued spark plug causes the insulator to crack.

c. Inspect for sign of tracking that occurred near the insulator tip instead of the center electrode (4).

d. Inspect for a broken or worn side electrode (3).

e. Inspect for a broken, worm, or loose center electrode (4) by shaking the spark plug.



(1) A rattling sound indicates internal damage.
(2) A loose center electrode (4) reduces the spark intensity.

f. Inspect for bridged electrodes (3, 4). Despites in the electrode (3, 4) reduce or eliminate the gap.

g. Inspect for worn of missing platinum pads on the electrodes (3, 4), if equipped.

h. Inspect for excessive fouling.

5. Inspect the spark plug recess area of the cylinder head for debris. Dirty or damaged threads can cause the spark plug not to seat correctly during installation.

Visual Inspection

1. Normal operation – Brown to grayish-tan with small amounts of white powdery deposits are normal combustion by-products from fuels with additives.

2. Carbon fouled – Dry, fluffy, black carbon or soot caused by the following conditions:

- Rich fuel injectiors
  - Leaking fuel injectiors
  - Excessive fuel pressure
  - Restricted air filter element
  - Incorrect combustion

- Reduced ignition system voltage output
  - Weak coil pack
  - Worn ignition wires
  - Incorrect combustion
  - Excessive idling or slow speeds under light loads can keep spark plug temperatures so low that normal combustion deposits may not burn off.

3. Deposit fouling – Oil, coolant, or additives that include substances such as silicone, very whit coating, reduce the spark intensity. Most powdery deposits will not effect spark intensity underless they form into a glazing over the electrode.

Charging System

General Description

The alternator is an electrical and mechanical components driven by a belt from engine rotation. It is used to charge the storage battery during the engine operation. The alternator is cooled by an external fan mounted behind the pulley. The fan pulls air through the holes in the back of the alternator. The air exits the front of the alternator, cooling it in the process. The valeo alternator also has an internal fan. This fan is mounted on the rotor. This fan pulls air through the holes in the back of the alternator to cool the rectifier bridge and regulator. The air exits the front of the alternator.

The alternator converts mechanical and magnetic energy to alternating current (AC) and voltage. This process is done by rotating a direct current (DC) electromagnetic field (rotor) inside a three phase stator. The alternating current and voltage (generated by the stator) are changed to direct current by a three phase, full wave rectifier system using six silicone rectifier diodes. Some alternators have three exciter diodes or a diode trio. They rectify the current needed to start the charging process. Direct current flows to the alternator output terminal.

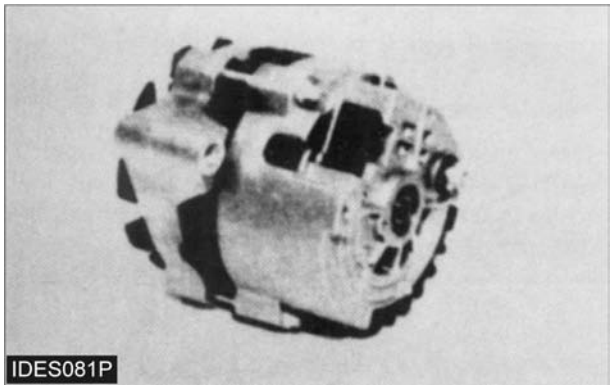
A solid state regulator is installed in or on the back of the alternator. Two brushes conduct current, through two slip rings, to the rotor field. Some alternators have a capacitor mounted on them. The capacitor protects the rectifier from high voltages. It also suppresses electrical noise through a radio, if equipped.

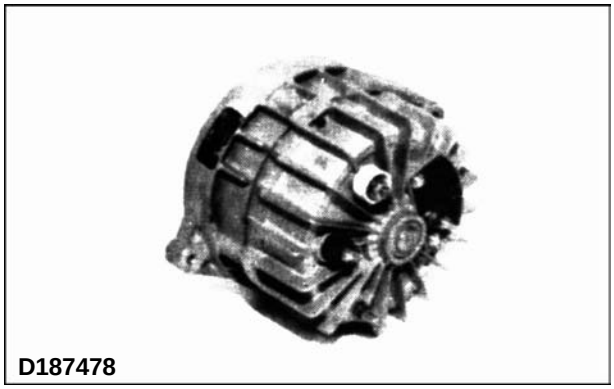
The alternator is connected to the battery through the ignition switch for alternator turn on. Therefore, alternator excitation occurs when the switch is turned on.

Alternators

The alternators used on these engines have three phase, full-wave, rectified output. They are the brush type. Refer to the Alternator Coverage chart for detailed systems operation information

ALTERNATOR COVERAGE	
Alternator Part Number	Manufacturer/ Series
D167411	Korea-Delphi CS121D
D187478	MICO/K1 Sealed





Troubleshooting

Charging system defect is almost caused by lack of pan belt tension and faulty function of wiring, connector, and voltage regulator.
One of most important thing during troubleshooting of charging system is determining the reason between overcharging and lack of charging. So, prior to inspection of alternator, check the battery for charging. Faulty alternator causes the following symptoms.

1. Faulty battery charging

1) IC regulator fault (Short circuit)

2) Field coil fault

3) Main diode fault

4) Stator coil fault

5) Brush contact fault

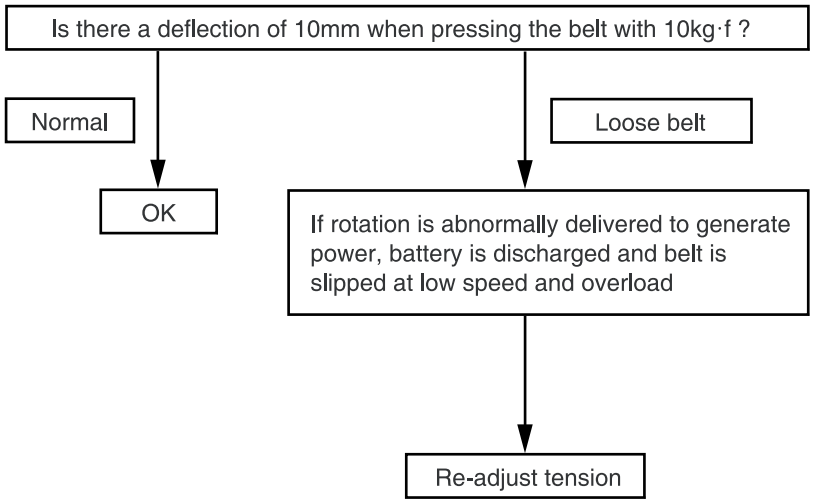
2. Overcharging : IC regulator fault(Short circuit)
Other faults such as voltage adjusting problem except above symptoms rarely happen.

Refer to the following troubleshooting table

Symptom	Possible cause	Remedy
With ignition switch ON, charging warning lamp does not illuminate	Fuse cut off	Replace
	Bulb burnt out	Replace
	Loose wiring connection	Retighten
	Bad connection of L terminal	Inspect and replace wiring
With the engine started, warning lamp is not turned off (Battery needs often charging)	Loose or worn drive belt	Correct or replace
	Fuse cut off	Replace
	Circuit breaker cut off	Reset or replace
	Faulty voltage regulator or alternator	Inspect alternator
	Faulty wiring	Repair
	Corrosion or wear of battery cable	Repair or replace
Overcharged	Faulty voltage regulator (Charging warning lamp illuminates)	Replace
	Voltage detection wring fault	Replace
Battery is discharged	Loose or worn drive belt	Correct or replace
	Loose wiring connection	Retighten
	Short circuit	Repair
	Circuit breaker cut off	Reset or replace
	Ground fault	Repair
	Faulty voltage regulator (Charging warning lamp illuminates)	Inspect alternator
	Battery out	Replace

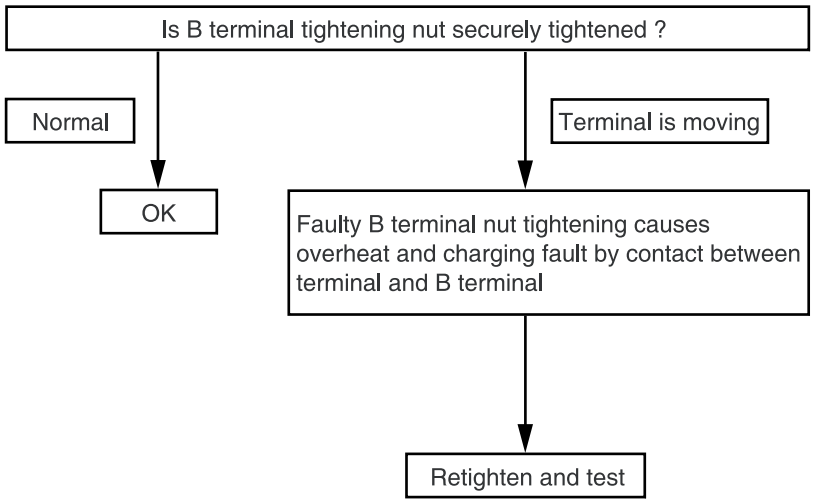
Troubleshooting Procedure

Inspection before Starting

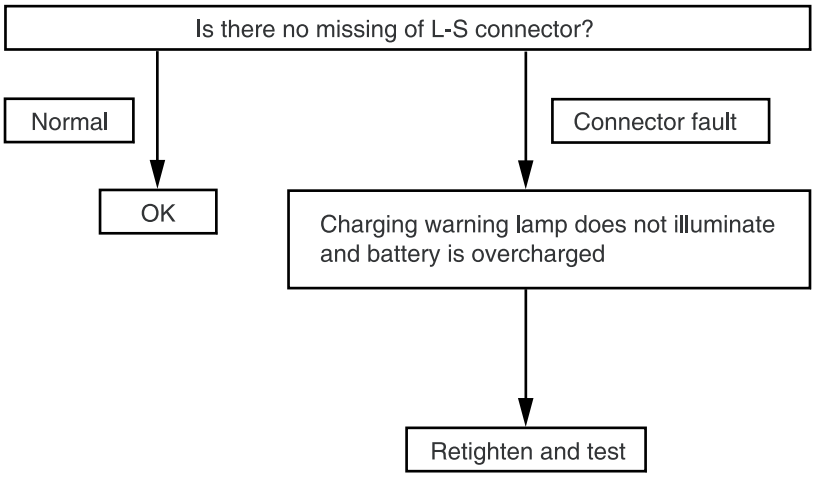

Is there a deflection of 10mm when pressing the belt with 10kg·f ?
Normal
Loose belt
OK
If rotation is abnormally delivered to generate power, battery is discharged and belt is slipped at low speed and overload
Re-adjust tension

L4GC312A

1. Alternator and drive belt tension inspection.

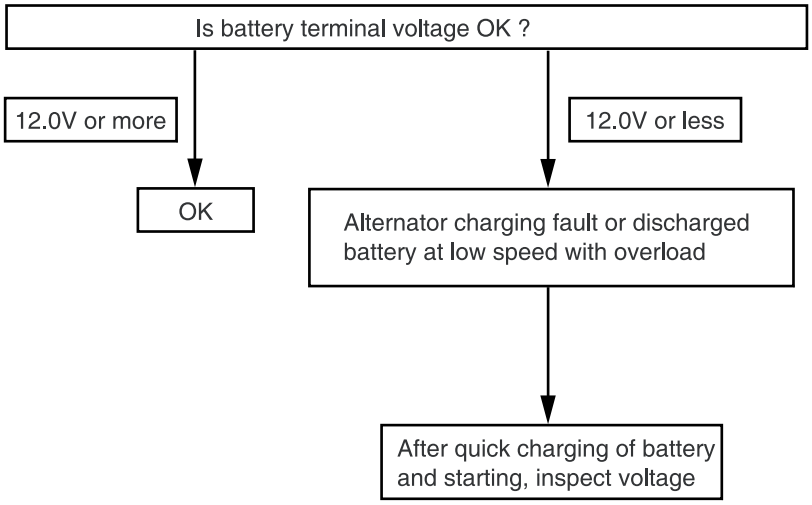

Is B terminal tightening nut securely tightened ?
Normal
Terminal is moving
OK
Faulty B terminal nut tightening causes overheat and charging fault by contact between terminal and B terminal
Retighten and test

L4GC313A


Is there no missing of L-S connector?
Normal
Connector fault
OK
Charging warning lamp does not illuminate and battery is overcharged
Retighten and test

L4GC314A

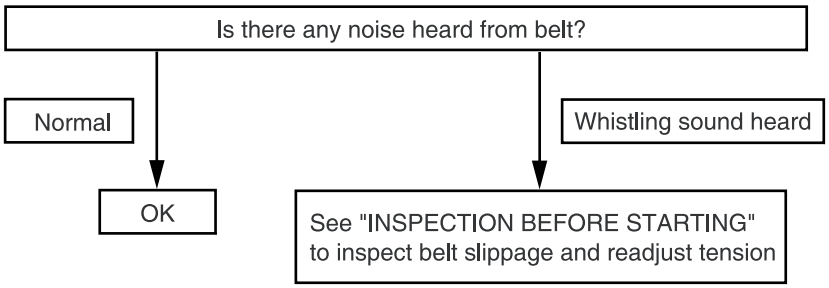
2. Alternator and outer terminal connection inspection.


Is battery terminal voltage OK ?
12.0V or more
12.0V or less
OK
Alternator charging fault or discharged battery at low speed with overload
After quick charging of battery and starting, inspect voltage

L4GC315A

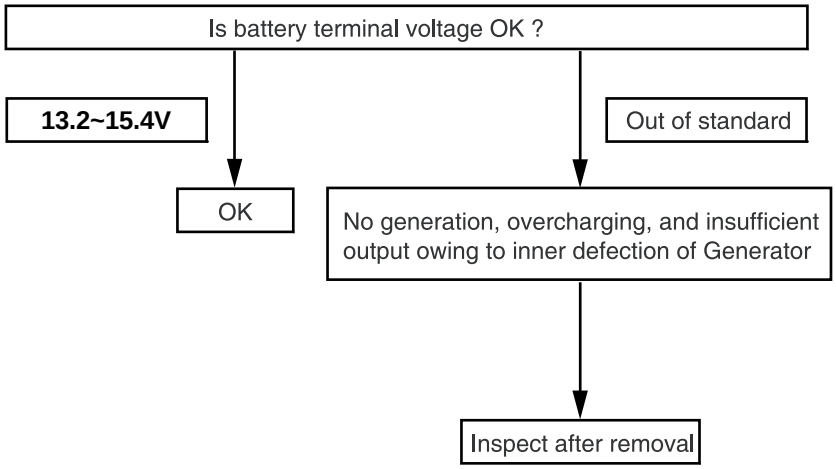
3. Battery outer terminal inspection.

Inspection after Starting


Is there any noise heard from belt?
Normal
Whistling sound heard
OK
See "INSPECTION BEFORE STARTING" to inspect belt slippage and readjust tension

L4GC318A

1. When starting, belt slip and noise inspection

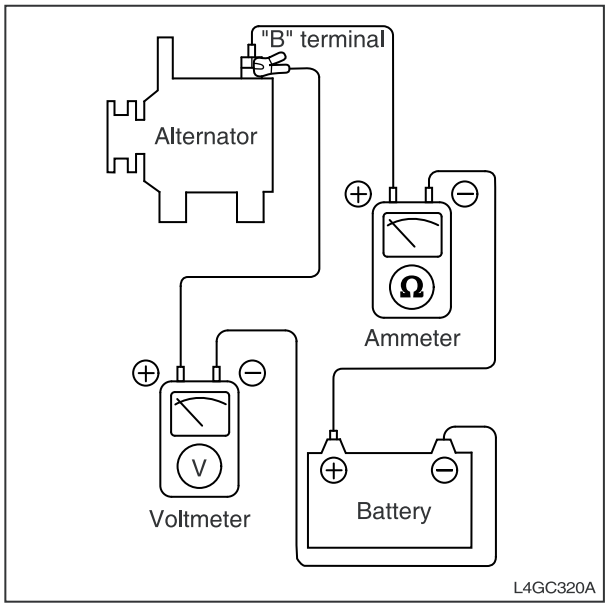

Is battery terminal voltage OK ?
13.2~15.4V
Out of standard
OK
No generation, overcharging, and insufficient output owing to inner defection of Generator
Inspect after removal

L4GC319A

2. Inspection of battery voltage at idling (At this time charge battery only)

Drop of Electric Pressure Test of Alternator Output Wire

This test is to check that wiring is correctly connected between the alternator “B“ terminal and battery (+) terminal.



Preparation

1. Turn the ignition switch OFF.

2. Disconnect the battery ground cable.

3. Disconnect the alternator output wire from the alternator “B” terminal.

4. Connect a DC ampere meter (0-100A) between the terminal and the disconnected output wire. Connect (+) lead wire to the terminal “B” and (-) lead wire to the disconnected output wire.

NOTE: In case of using a clamp type ammeter, it is possible to measure current without disconnecting the harness.

5. Connect a digital voltmeter between the alternator “B” terminal and the battery (+) terminal. Connect (+) lead wire to the terminal and (-) lead wire to the battery (+) terminal.

6. Connect the battery ground cable.

7. Be sure that the hood is opened.

Test

1. Start the engine.

2. Repeating ON and OFF of headlight and small light, adjust the engine speed until an ammeter reads 20A and at that time measure voltage.

Result

1. If voltmeter reading is within the standard, it is normal.

2. If voltmeter reading is more than the standard, mostly wiring is faulty. In this case, inspect wirings between the alternator and the battery (+) terminal as well as between the alternator “B” terminal and the fusible link.

3. Also prior to re-test, check and repair the connecting part for looseness and the harness for discoloration by overheating.

4. After test, adjust the engine speed at idle and turn the light and ignition switch OFF.

5. Disconnect the battery ground cable.

6. Disconnect the ammeter and voltmeter.

7. Connect the alternator output lead wire to the alternator “B” terminal.

8. Connect the battery ground cable.

Output Current Test

This test is to check that the alternator output current is identified with the rated current.

Preparation

1. Prior to test, inspect the following items and repair if necessary.

1) Be sure that the battery installed in the vehicle is normal. (See “Battery”)

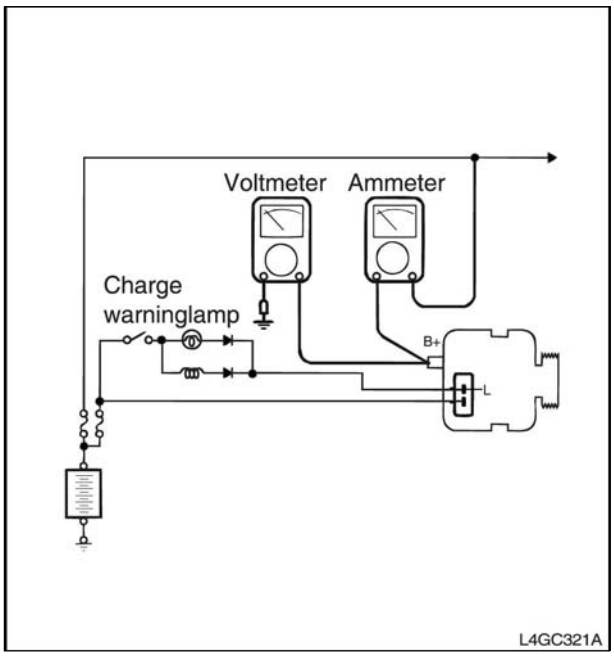
NOTE: When measuring output current, necessarily use a slightly discharged battery. Fully charged battery is not enough to use for correct test owing to insufficient load.

2) Inspect the drive belt for tension. (See “Engine body”)

2. Turn the ignition switch OFF.

3. Disconnect the battery ground cable.

4. Disconnect the alternator output wire from the alternator “B” terminal.



5. Connect a DC ampere meter (0-100V) between “B” terminal and the disconnected output wire. Connect (+) lead wire to the terminal “B” and (-) lead wire to the disconnected output wire.

NOTE: Do not use clips or equivalent owing to high current and Use bolts and nuts to tighten each connecting part securely.

6. Connect a volt meter (0-20V) between “B” terminal and the ground.
Connect (+) lead wire to the alternator “B” terminal and (-) lead wire to the proper position.

7. Connect the engine tachometer and then battery ground cable.

8. Be sure that the hood is opened.

Test

1. Be sure that voltmeter reading is identified with battery voltage.
If voltmeter reading is 0V, it means short circuit of wire between “B” terminal and the battery (-) terminal, fusible link cut off or ground fault.

2. Turn the headlight ON and start the engine.

3. With the engine running at 2,500 rpm, turn ON the high beam headlights, place the heater blower switch at ”HIGH” measure the maximum output current using a ammeter.

NOTE: This test should be done as soon as possible to measure the exact maximum current because output current drops rapidly after starting the engine.

Result

1. Ammeter reading should be as same as the load. If the reading is low even though the alternator output wire is normal, remove the alternator from the vehicle and inspect it.

Output current	As same as Elecrical load

NOTE: Output current varies according to electrical load or temperature of the alternator, so during test, lack of electrical load causes impossibility of measuring the rated output current. In this case, turn on headlight to induce the battery discharging or turn on other lights to increase the electrical load. If alternator temperature or ambient temperature is too high, it is impossible to measure the rated output current, so prior to re-test, necessarily drop the temperature.

Ambient temperature of voltage regulator(℃)	Voltage adjust(V)
-30	14.5 ~ 15.4
25	14.3 ~ 14.9
60	14.0 ~ 14.8
90	13.6 ~ 14.6

2. After test, adjust the engine speed at idle and turn the light and ignition switch OFF.

3. Disconnect the battery ground cable.

4. Disconnect the ammeter and voltmeter.

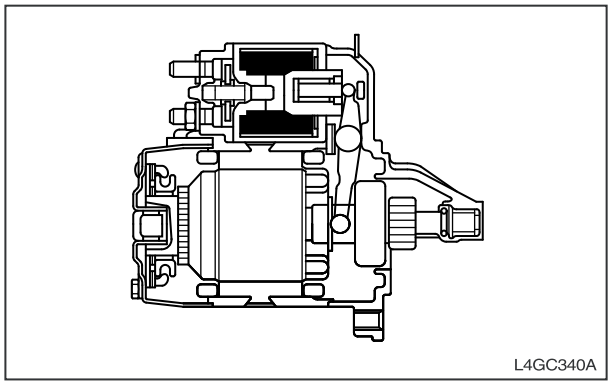
5. Connect the alternator output lead wire to the alternator “B” terminal.

6. Connect the battery ground cable.

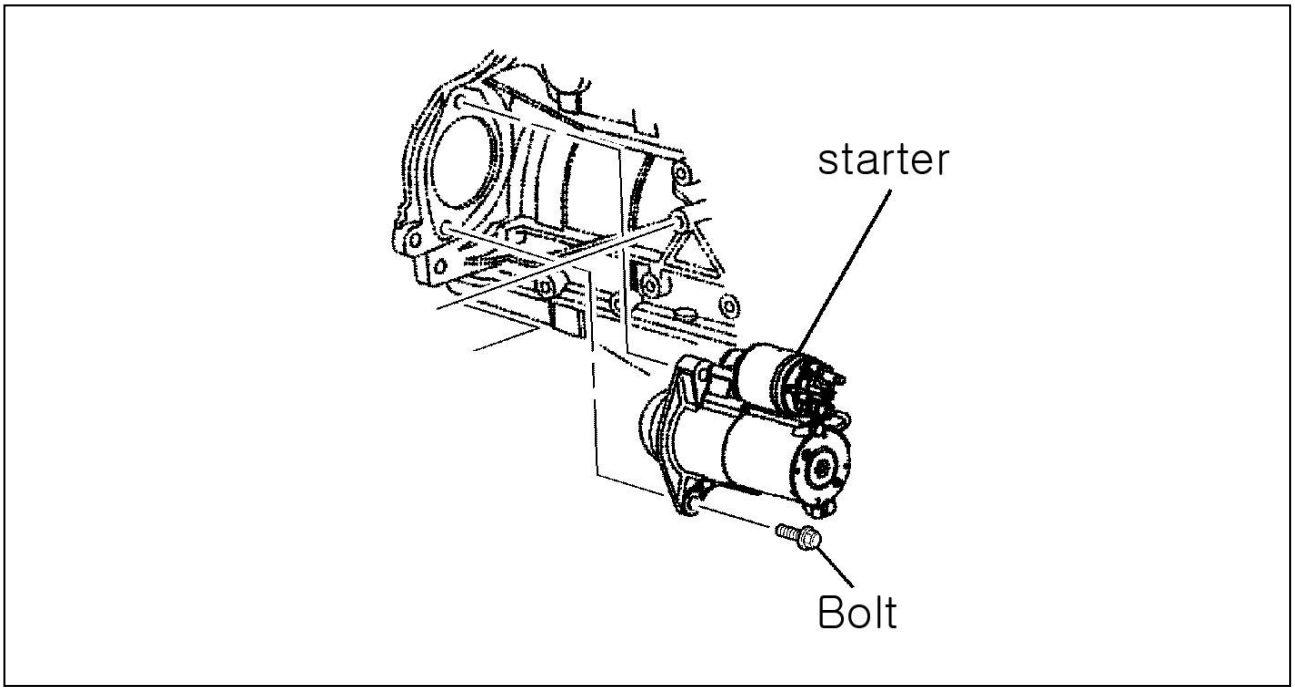
STARTING SYSTEM

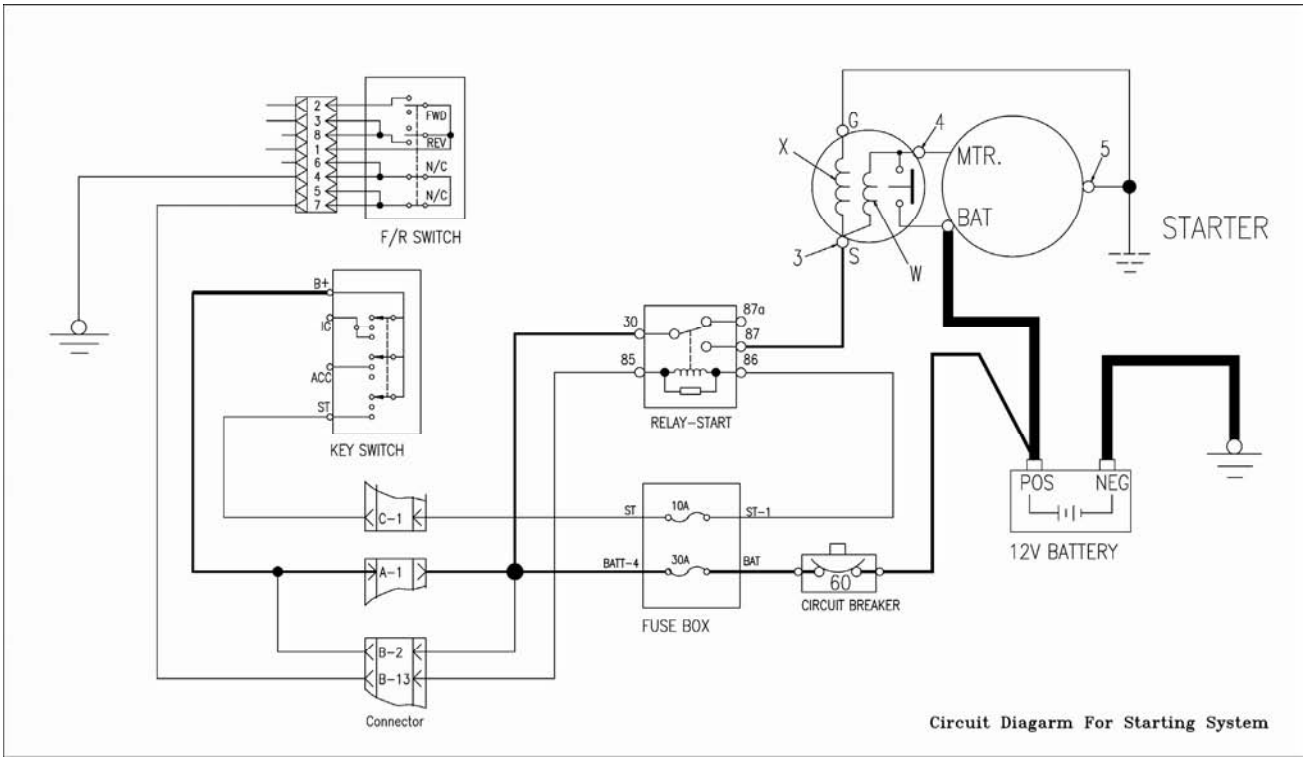
General Description

The starting motor is used to turn the engine flywheel lfast enough to make the engine run. The starting motor has a solenoid. When the ignition switch is activated, voltage from the electrical system will cause the solenoid to move the pinion toward the flywheel ring gear of the engine. The electrical contacts in the solenoid close the circuit between the battery and the starting motor just before the pinion engages the ring gear. This causes the starting motor to rotate. This type of motor "turn on" is a positive shift starting motor. When the engine begins to run, the overrunning clutch portion of the pinion drive prevents damage to the armature caused by excessive speeds. The clutch does this by breaking the mechanical connection. The pinion will stay meshed with the ring gear until the ignition switch is released. A return spring in the overrunning clutch returns the clutch to its rest position.



Components





Circuit Diagarm For Starting System

Diagnosis Procedure

The following simplified procedure is intended to help the serviceman determine if a starting motor needs to be removed and replaced or repaired. It is not intended to cover all possible problems and conditions, but to serve only as a guide. The most common 12 volt circuit is shown and discussed.

General Information

All starting systems are made up of four elements. They are the ignition switch, start relay, the starting motor solenoid and starting motor.

Start switches are relatively low current devices. They are rated to switch approximately 5 to 20 amps. Because the coil of a start relay [between test point 86 and 85] draws about 0.2 amp, the start switch can easily turn on the start relay and have long life.

The switch contacts of a typical start relay are rated to switch 30 amps. Because the solenoid requires 5 to 20amps the start relay can easily switch this load.

The starting motor solenoid has two functions:

1. Engages the pinion with flywheel.

2. Is a high current switch rated about 1000 amps that actually turns on the starting motor.

The starting motor solenoid has two coils. Pull-in coil (W) draws about 40 amps and hold-in coil (X) requires about 5 amps. The instant the start relay closes, both coils (W) and (X) receive power. Battery voltage is applied to the high end of both coils, at test point (3) which is the start (S) terminal. The low end of hold-in coil (X) is permanently grounded to the ground post or motor housing of the starting motor. Grounding for the low end, test point (4), of pull-in coil (W) is momentary, and takes place through the DC resistance of the starting motor. As soon as magnetic force builds in both coils, the pinion moves toward the flywheel ring gear. The pinion will stop short of engagement of the flywheel ring gear. Only then will the solenoid contacts close to power the starting motor. This temporarily removes the ground from pull-in coil (W), and puts battery voltage on both ends of it while the starting motor cranks. During this period, the pull-in coil is out of the circuit. Cranking continues until power to the solenoid is broken by releasing the ignition switch.

The result of these switches and relays is to permit a 5 amp dash-mounted switch to turn on a 500 to 1000amp motor used to crank an engine. Battery voltage (power) available during cranking varies according to the temperature of the batteries. The following chart is a guide as to what to expect from a normal system.

TYPICALSYSTEM VOLTAGE DURING CRANKING AT VARIOUS AMBIENT TEMPERATURES	
Temperature	12V System
-23 to -7 C (-10 to 20 F)	6 to 8 Volts
-7 to 10 C (20 to 50 F)	7 to 9 Volts
10 to 27 C (50 to 80 F)	8 to 10 Volts

Figure 1
The next chart shows maximum acceptable voltage loss in the high current battery circuit feeding the starting motor. These values are maximums for machines of approximately 2000 SMH and up. Newer machines would be less than those shown.

MAXIMUM ACCEPTABLE SYSTEM VOLTAGE DROPS DURING CRANKING	
Circuit	12V System
Battery(-) post to starting motor (-) terminal	0.7 Volts
Battery (+) post to solenoid (+) terminal	0.5 Volts
Solenoid Bat terminal to solenoid Mtr terminal	0.4 Volts

Figure 2
Voltages greater than those shown are most often caused by loose and/or corroded connections or defective switch contacts.

Diagnosis Procedure

TOOLS NEEDED	
Digital Multimeter or Equivalent	1
DC Clamp-On Ammeter or Equivalent	1

NOTICE

Do not operate the starting motor for more than 30seconds at a time. After 30 seconds, the cranking must be stopped for two minutes to allow the starting motor to cool. This will prevent damage to the starting motor due to excessive heat buildup.

If the starting motor cranks real slow or does not crank at all, do the following procedure:

1. Measure battery voltage at the battery posts with the multimeter while cranking or attempting to crank the engine. Make sure to measure the battery posts. Do not measure the cable post clamps.

2. Is battery voltage equal to or greater than shown in Figure 1?

- If the battery voltage is correct, go to Step 3.
- If the battery voltage is too low, Charge or replace the battery.

NOTE: Alow battery can be caused by battery condition or a shorted starting motor.

3. Measure current draw on the (+) battery cable between the battery and the starting motor solenoid with the clamp-on ammeter. The maximum current draw allowed is 350 Amp. At temperatures below27°C (80°F), the voltage will be less and the current draw will be higer. If current draw is too much, the starting motor has a problem and must be removed for repair or replacement.

NOTE: If voltage at the battery post is within approximately 2 volts of the lowest value in the applicable temperature range of Figure1 and if the large starting motor cables get hot, then the starting motor has a problem and the Ammeter test is not needed.

4. Measure starting motor voltage from test point (4) to (5) with the multimeter while cranking or attempting to crank the engine.

5. Is voltage equal to or greater than shown in Figure1?

- If the starting motor voltage is correct, the battery and starting motor cables down to the motor are within specifications. Go to Step 8.
- If the starting motor voltage is low, the voltage drop between the battery and the starting motor is too great. Go to Step 6.

6. Measure the voltage drops in the cranking circuits with the multimeter. Compare the results with maximum voltage drops allowed in Figure 2.

7. Are all the voltages within specifications ?

- If the voltage drops are correct, go to Step 8, to check the engine.
- If the voltage drops are too high, repair and/ or replace the faulty electrical component.

8. Rotate the crankshaft by hand to make sure it is not locked up. Check oil viscosity and any external loads that would affect engine rotation.

9. Is the engine locked up or hard to turn ?

- If it is, repair the engine as required. If the engine is not hard to turn, go to Step 10.

10. Does the starting motor crank?

- If it does crank, remove the starting motor for repair and/or replacement.
- If it does not crank, check for blocked engagement of the pinion and flywheel ring gear.

NOTE: Blocked engagement and open solenoid contacts will give the same electrical symptoms.

Start Relay Tests

Relay

1. Put the multimeter on the 200 ohm scale.

2. Put the multimeter lead to the 85 and 86 terminals.

3. The indication on the meter must be 82 5 ohms. If the indication is not correct, the start relay must be replaced.

4. Put the multimeter leads to the 30 and 87 terminals.

5. The indication must be "OL"(Over Load). If the indication is not correct, the start relay must be replaced.

6. Connect WH wire to 86 and BK wire to 85 terminal with the ignition switch to start position. Put the meter lead to 30 and 87 terminal.

7. The indication must be Zero ohm. If the indication is not correct the start relay must be replaced.

Troubleshooting

Starting system problem can be classified into “Start motor is not operating”, “Start motor is operating but engine is not starting” , and “There is a lot of time taken to start engine”.

When the starting system has problems, before removing the start motor, find where the problem happens. Generally if it is difficult to start, there are problems in ignition system, fuel system, and electrical system. In this case, necessarily inspect and repair step by step, or the same problem will happen.

Symptom	Possible cause	Remedy
Impossible cranking	Low battery charging voltage	Charge or replace
	Loose, corroded or worn battery cable	Repair or replace
	Inhibitor switch fault	Adjust or replace
	Circuit breaker cut off	Reset or replace
	Start motor fault	Repair
	Ignition switch fault	Replace
Slow cranking	Low battery charging voltage	Charge or replace
	Loose, corroded or worn battery cable	Repair or replace
	Start motor fault	Repair
Continuous rotating of start motor	Start motor fault	Repair
	Ignition switch fault	Replace
	Start relay fault	Replace
Start motor is rotating but engine is not cranking	Short circuit of wiring	Repair
	Worn or broken pinion gear tooth or motor fault	Repair
	Worn or broken ring gear tooth	Replace flywheel ring gear or torque converter

Starter Repair

Removal

Remove or disconnect

⚠ WARNING

Always disconnect the cable at the battery before you make repairs to the engine. Disconnect the cable at the negative terminal first. Install a tag on the battery terminals first. Install a tag on the battery terminals so that no one connects the cable on the terminal.

1. Discount battery negative cable at negative terminal.

2. Disconnect the battery positive cable at positive terminal.

3. Put labels on wires and cables prior to disconnecting to aid in correct installation.

4. Disconnect wires and cables from starter.

5. Hold starter so it won't fall. Remove capscrews that fasten the starter to the flywheel housing. Install capscrews to fasten the starter to the flywheel housing.

Installation

Install or connect

1. Place starter in position in flywheel housing. Install capcrews to fasten the starter to the flywheel housing. Tighten cap screws to 38 N•M (28 lb•ft)

2. Connect wires and cables as labeled in removal.

3. Connect the battery positive cable at positive terminal.

4. Connect battery negative cable at negative terminal.

Chapter 5. ENGINE MANAGEMENT SYSTEM (EMS)

General Information

Specifications

SECM and Sensor/Switch Inputs

Components	Q'ty		Items	Specifications
	G424FE	G424F		
Environmental / Electrical Specifications	None	None	Ambient Operating Temperature Operating Voltage	-20 °F to 221°F [-29 °C to 105 °C] 8-16 Vdc
Engine Control Module (SECM 48)	1	1	Operating Temperature Operating Voltage Operating Environment	-20 °F to 221°F [-29 °C to 105 °C] 8-16 Vdc SECM microprocessor may reset at voltages below 6.3 Vdc On-engine mounting, underhood automotive
Camshaft Position Sensor	0 (LP) 1 (Dual Fuel)	None	Type Output Voltage	Hall effect sensor 0 – 5 Volts
Crankshaft Position Sensor	1	1	Type Tooth wheel	VR sensor 58X
TMAP Sensor	1	1	MAP sensor Intake Air Temp Sensor	Piezo- Resistivity type 0-5V output Thermistor type (built in MAP sensor) 2.0-3.0kohms at 20°C
LP Fuel Temperature Sensor	1	None	Type Resistance	Thermister 2.5kΩ@20℃ 243Ω@90℃
Oxygen Sensor	2	None	Type Output Voltage	Zirconia Sensor (Heated) 0 - 1V
Coolant Temperature Sensor	1	1	Type Resistance	Thermistor Type 1.0-4.0 kohms at 20°C
Acceleration Pedal Angle Sensor	1	1	Type APP1(Low idle) APP2(Low idle) APP1(Hi idle) APP2(Hi idle)	Hall IC 0.4 ± 0.1 V 4.5 ±0.1 V 3.6 ±0.15 V 1.39 ± 0.15 V
Engine Oil Pressure Switch	1	1	Actuation Pressure	0.3 +/- 0.1 kgf/cm^2

Components	Q'ty		Items	Specifications
	G424FE	G424F		
Transmission Oil Temperature Switch	1	1	Actuation Temperature	125°C
Ground speed limit switch	option	option	Type Actuation Pressure	Normal Open 145 ± 28 kPa

Electronic Throttle System

Components	Q'ty		Items	Specifications
	G424FE	G424F		
Electronic Throttle System	1	1	Minimum Electrical Resistance of Throttle Actuator	1.5 ohms

Ignition System Components Specification

Components	Q'ty		Items	Specifications
	G424FE	G424F		
Ignition Coil Ass'y	1	1	Coil Type Coil Supply Voltage Primary Resistance	Inductive 8-16 Vdc 0.15 ohm
Spark Plug	4	4	Air Gap	0.8-0.9 mm

LP Fuel Components Specification

Components	Q'ty		Items	Specifications
	G424FE	G424F		
LP Fuel System Requirements	-	-	Operating Temperature LPG Composition Requirements	-20 °F to 221°F [-29 °C to 105 °C] HD5 / HD10 LPG. Failure to use fuel compliant with HD5 or HD10 standards will void the user warranty.
LP Fuel Filter	1	1	Fuel Filter Micron Size	40 micron
LP Fuel Lock-off	1	1	Electrical Resistance	20~25Ω
N-2007 LP Regulator For G424FE	1	None	Fuel Supply Pressure Fuel Inlet Fitting Fuel Outlet Fitting Fuel Supply Temperature at Tank Outlet Primary Pressure Tap Max Flow Coolant Flow to Vaporizer Fuel Outlet Pressure Setpoints Mounting	10 psi to 250 psi (68.95 kPa to 1723.69 kPa) 1/4" NPT Two 3/4" NPT fittings with one plugged and one 1/8" NPT fitting with plug -20 °F to 120 °F [-29 °C to 49 °C] 1/8" NPT with plug 50 lbm/hr LPG > 1.0 gpm/100bhp, equipped with 140 °F (60 °C) thermostat -0.7 ± 0.2 inH2O @ 1.7 lbm/hr LPG (-1.744 ± 0.498 mbar) @ 1.7 lbm/hr LPG) -2.0 ± 0.2 inH2O @ 50 lbm/hr LPG (-4.982 ± 0.498 mbar) @ 50 lbm/hr LPG) Regulator should be installed with centerline of outlet at least 15° below horizontal to permit drainage of any liquid precipitates from LPG fuel. Diaphragm should be vertically oriented.

Components	Q'ty		Items	Specifications
	G424FE	G424F		
N-2001 LP Regulator For G424F			Fuel Supply Pressure	10 psi to 250 psi (69 kPa to 1724 kPa)
			Fuel Inlet Fitting	1/4" NPT
			Fuel Outlet Fitting	One 3/4" NPT and one 1/8" NPT fitting with plug
			Fuel Supply Temperature At Tank Outlet	-20 °F to 120 °F [-29 °C to 49 °C]
	None	1	Primary Pressure Tap	1/8" NPT with plug
			Max Flow	50 lbm/hr LPG
			Coolant Flow to Vaporizer	>1.0 gpm/100bhp, equipped with 140 °F (60°C) thermostat
			Fuel Outlet Pressure Setpoints	-0.5 ± 0.35 inH2O@1.7 lbm/hr LPG (-1.25 ± 0.87 mbar)@1.7 lbm/hr LPG) -1.35 ± 0.5 inH2O@32.1 lbm/hr LPG (-3.36 ± 1.25 mbar)@32.1 lbm/hr LPG)
CA100 Mixer For G424FE			Fuel	LPG
			Fuel Inlet Fitting	1/2" NPT Fuel inlet fitted with Delphi temperature sensor
			Air Intake Flange	2.25" (57.15mm) ID inlet, four #10-24 screws in 1.94" (49.28mm) square pattern
			Mixer Mounting Flange	1.87" (47.49mm ID outlet, four #12-24 screws arranged in a rectangular pattern
	1	None	Reference Pressure Ports	Two 1/8-NPT ports. Pressure readings must be identical within 0.25 inH2O (0.623 mbar) at all airflows.
			Air Valve Vacuum (AVV) Port Size	1/4-28 UNF
			Fuel Inlet Adjustments	None
			Idle Air Adjustment	None
			Mounting	Suitable for on-engine mounting in vertical orientation

Components	Q'ty		Items	Specifications
	G424FE	G424F		
CA100 Mixer For G424F	None	1	Fuel	LPG
			Fuel Inlet Fitting	1/2" NPT Fuel inlet fitted with Delphi temperature sensor
			Air Intake Flange	2.25" (57.15mm) ID inlet, four #10-24 screws in 1.94" (49.28mm) square pattern
			Mixer Mounting Flange	1.87" (47.49mm ID outlet, four #12-24 screws arranged in a rectangular pattern
			Reference Pressure Ports	1/4-1/8 NPT ports. Pressure readings must be identical within 0.25 inH_2O (0.623 mbar) at all airflows.
			Air Valve Vacuum (AVV) Port Size	1/4-28 UNF
			Fuel Inlet Adjustments	Power valve
			Idle Air Adjustment	Idle adjustment screw
			Mounting	Suitable for on-engine mounting in vertical orientation
Fuel Trim Valve (FTV)	2	None	Actuator Type Operating Voltage	On/off two-position valve compatible with LPG 8-16 Vdc

Gasoline Fuel Components Specification

Components	Q'ty		Items	Specifications
	G424FE	G424F		
Gasoline System Requirements	-	-	Gasoline Requirements	Unleaded gasoline of 87 octane or higher is recommended
Gasoline Fuel Pump	1	None	Type	Electrical, In-Tank
Gasoline Fuel Filter	1	None	Type	High pressure type (built in Fuel Pump Assembly)
Gasoline Pressure Regulator	1	None	Pressure	350 kPa (49.8 psi) built in Fuel Pump Assembly
Fuel Injector	4	None	Type Coil resistance	Electric-magnetic 12 - 14 ohms

Service Standard

Basic Idle rpm (After warm up)	No Load	750±15 rpm
Ignition Timing (After warm up, at idle)	BTDC 5°±5°	

Tightening Torques

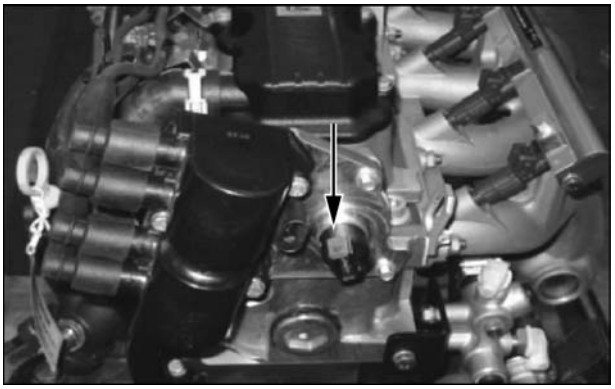
Items	N·m	kgf·m	1bf·ft
Heated Oxygen Sensor (HO2S, Sensor 1)	50 ~ 60	50 ~ 60	36. 2 ~ 43.4
Heated Oxygen Sensor (HO2S, Sensor 2)	50 ~ 60	5.0 ~ 6.0	36.2 ~ 43.4
Crankshaft Position Sensor (CKPS)	6	0.6	4.3
Camshaft Position Sensor (CMPS)	4 ~ 6	0.4 ~ 0.6	2.9 ~ 4.3
Engine Coolant Temperature Sensor (ECTS)	15 ~ 20	1.5 ~ 2.0	10.8 ~ 14.5
Delivery pipe installation	22 ~ 28	2.2 ~ 2.8	15.7 ~ 20.3

Component Location

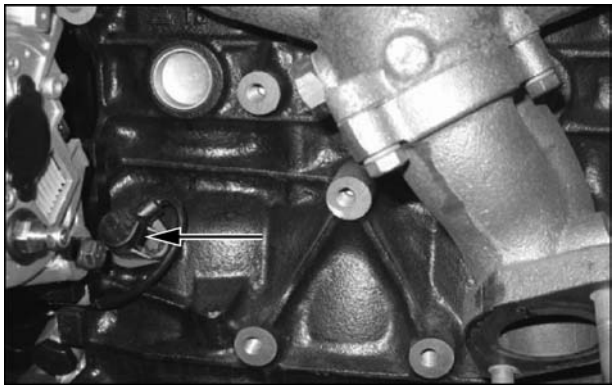
Engine Control Module (SECM48)



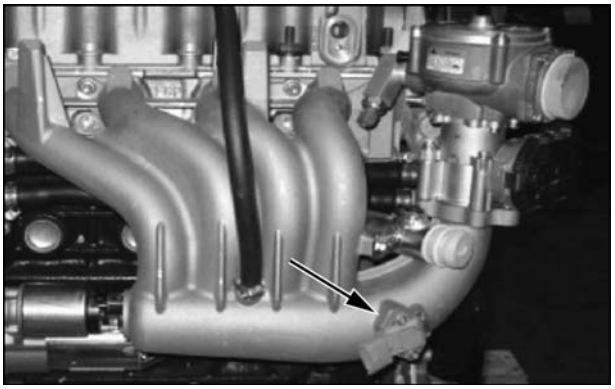
Camshaft Position Sensor



Crankshaft Position Sensor



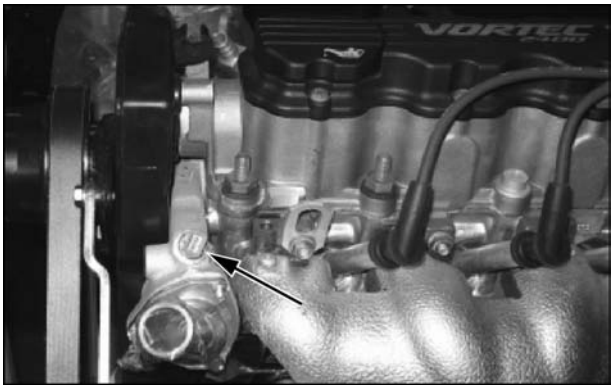
TMAP Sensor



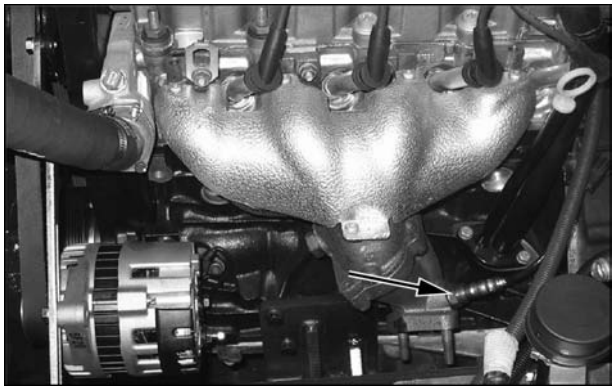
LP Fuel Temperature Sensor



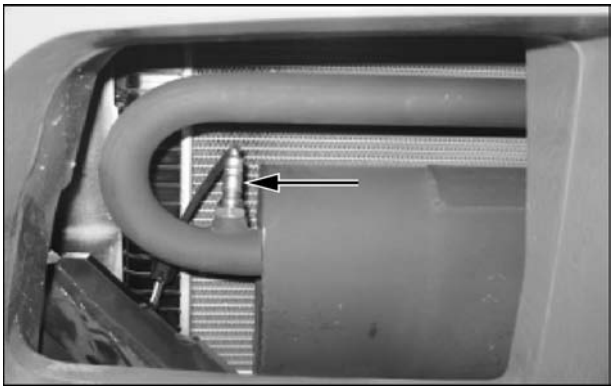
Coolant Temperature Sensor



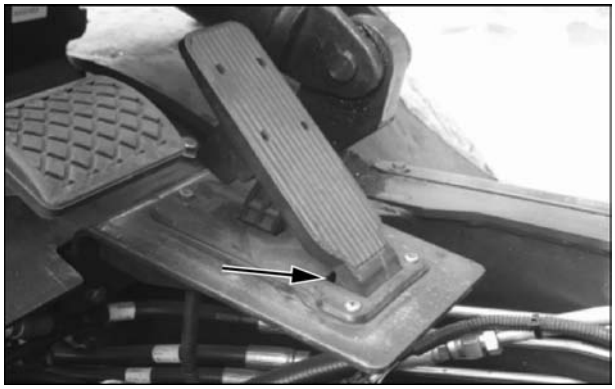
Pre-Catalyst Oxygen Sensor



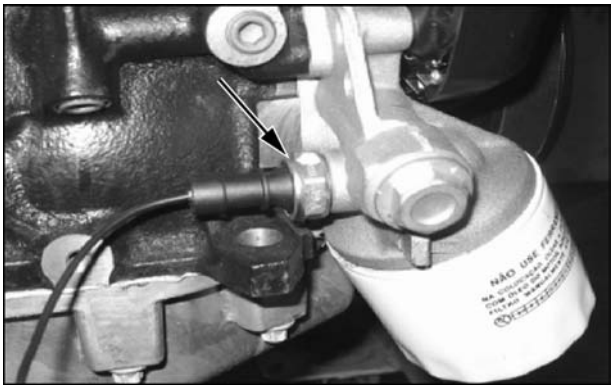
Post-Catalyst Oxygen Sensor



Pedal Angle Sensor



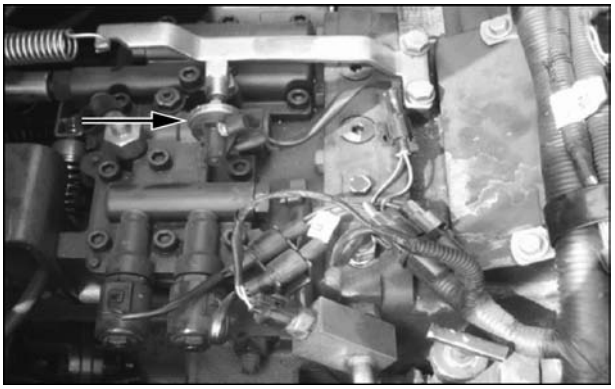
Engine Oil Pressure Switch



Transmission Oil Temperature Switch



Ground speed limit switch (option)



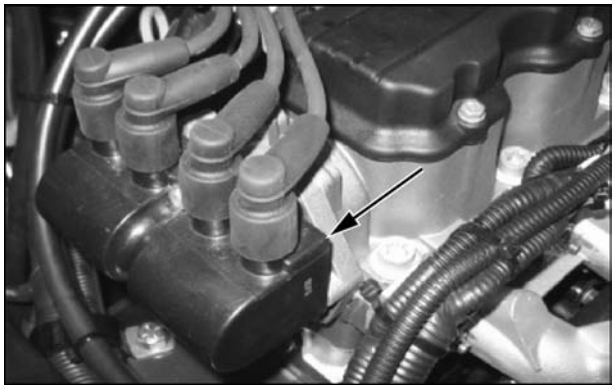
Electronic Throttle Body



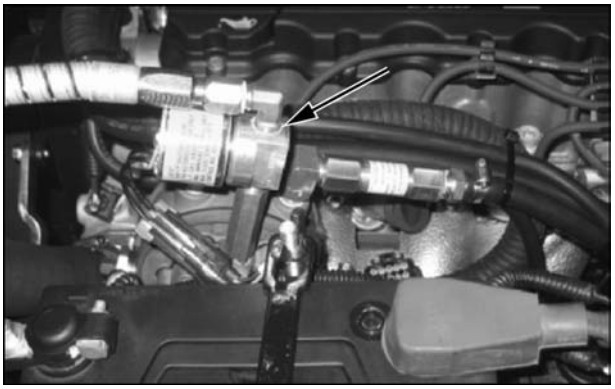
Fuel Trim Valve(FTV)



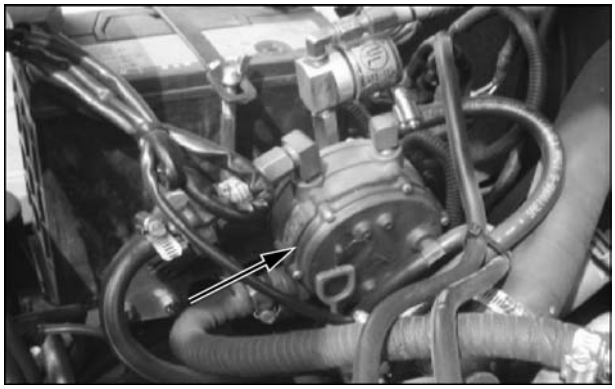
Ignition Coil



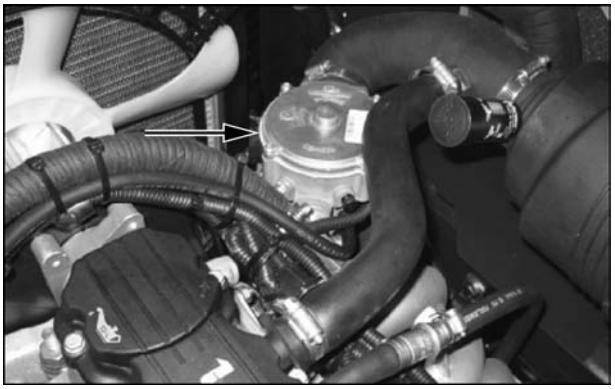
LP Fuel Lock-off



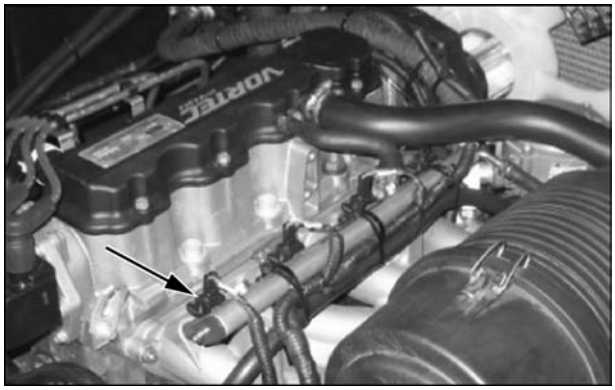
N-2007 LP Regulator



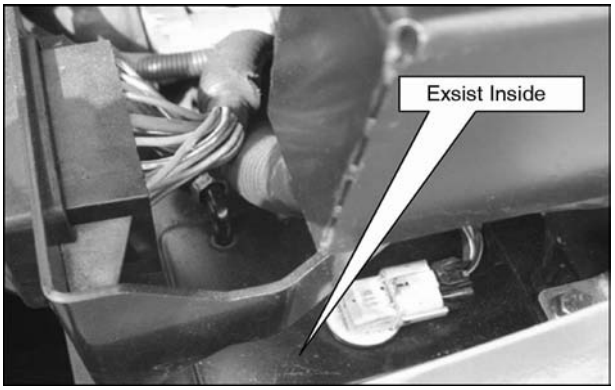
CA100 Mixer



Gasoline Injectors and fuel rail



Gasoline Fuel Pump Ass'y



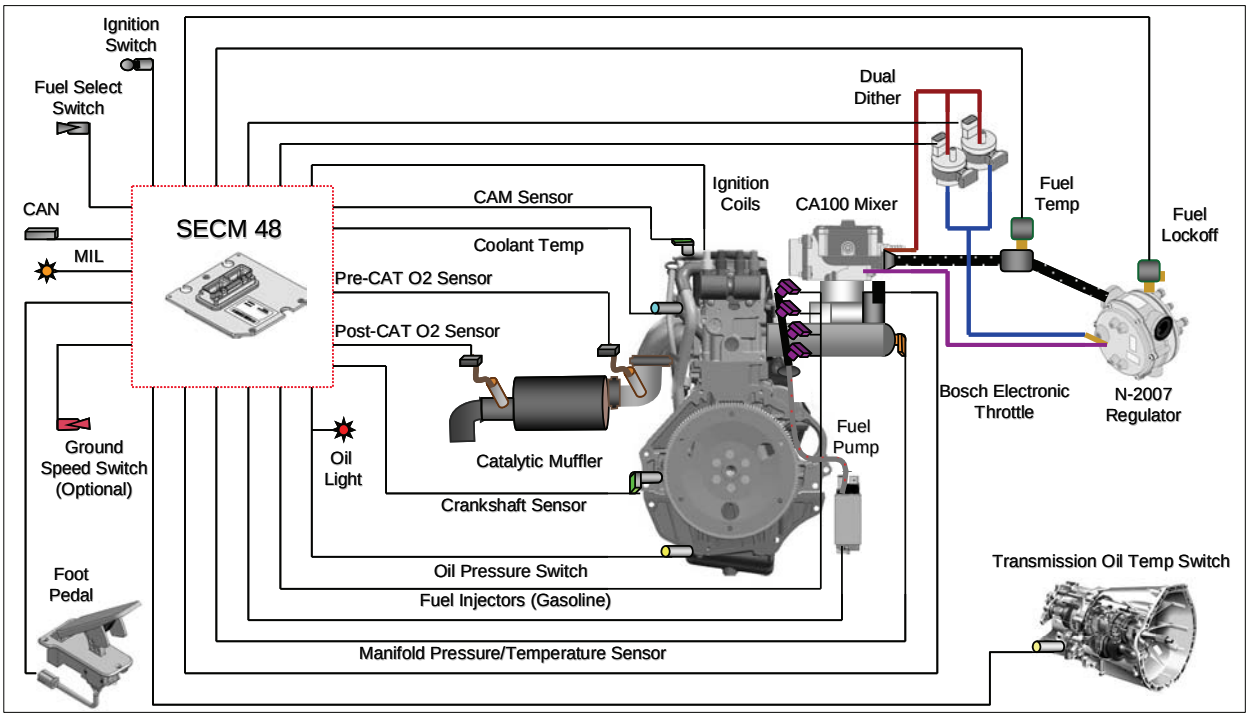
G424FE EMS (Engine Management System) Overview

General Description

MI-07 control system provides a complete, fully integrated engine management system that meets or exceeds 2007 emission standards for Large Spark Ignited (LSI) engines established by the California Air Resources Board (CARB) and the Environmental Protection Agency (EPA).

The control system is applicable to naturally aspirated engines running on LPG and/or gasoline. It provides accurate, reliable, and durable control of fuel, spark, and air over the service life of the engine in the extreme operating environment found in heavy-duty, under hood, on-engine electronic controls.

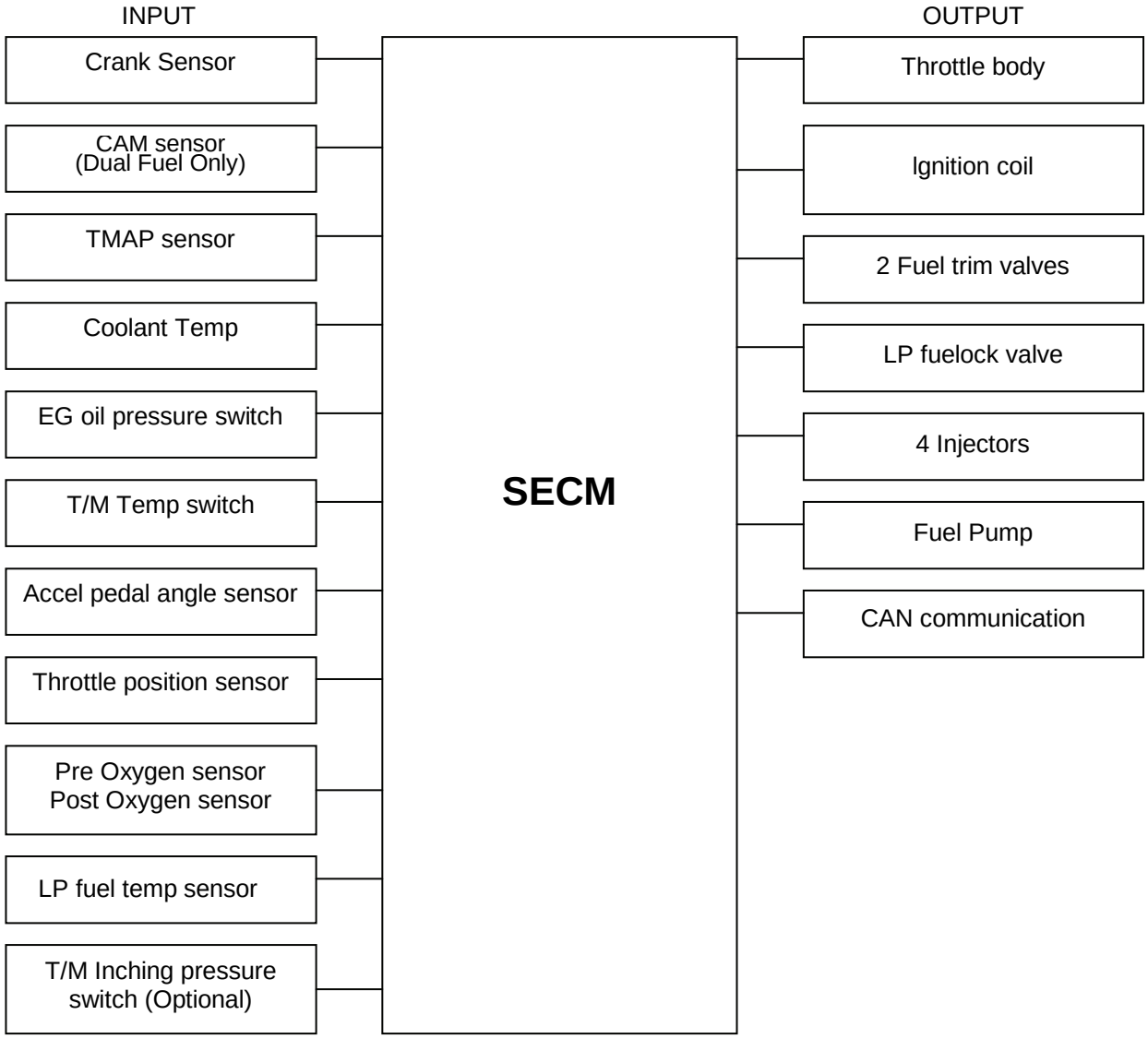
MI-07 is a closed loop system utilizing a catalytic muffler to reduce the emission level in the exhaust gas. In order to obtain maximum effect from the catalyst, an accurate control of the air fuel ratio is required. A small engine control module (SECM) uses two heated exhaust gas oxygen sensors (HEGO) in the exhaust system to monitor exhaust gas content. One HEGO is installed in front of the catalytic muffler and one is installed after the catalytic muffler.



[Figure 1] MI-07 Dual Fuel System for G424FE Engine

The SECM makes any necessary corrections to the air fuel ratio by controlling the inlet fuel pressure to the air/fuel mixer by modulating the dual fuel trim valves (FTV) connected to the regulator. Reducing the fuel pressure leans the air/fuel mixture and increasing the fuel pressure enriches the air/fuel mixture. To calculate any necessary corrections to the air fuel ratio, the SECM uses a number of different sensors to gain information about the engine's performance. Engine speed is monitored by the SECM through a Variable reluctance (VR) sensor. Intake manifold air temperature and absolute pressure are monitored with a TMAP sensor. MI-07 is a drive-by-wire (DBW) system connecting the accelerator pedal to the electronic throttle through the electrical harness; mechanical cables are not used. A throttle position sensor (TPS) monitors throttle position in relation to the accelerator pedal position sensor (APP) command. Even engine coolant temperature and adequate oil pressure are monitored by the SECM. The SECM controller has full adaptive learning capabilities, allowing it to adapt control function as operating conditions change. Factors such as ambient temperature, fuel variations, ignition component wear, clogged air filter, and other operating variables are compensated.

Dual Fuel System of G424FE (certified engine system)



A dual fuel system operates on either LPG or gasoline. The fuel type can be switched while the engine is stopped or running at low speeds and low loads. The fuel selection switch is a three-position type where the center position is fuel off.

MPI (multi-point injection) system is used for G424FE dual fuel engine. On gasoline, the camshaft sensor along with the crankshaft sensor is used to control the fuel injectors and feedback from oxygen sensor is used by the SECM to adjust the gasoline delivery based on the exhaust emissions.

MI-07 System Components

The MI-07 control system provides electronic control to the following subsystems on mobile industrial engines:

- Fuel delivery system
- Spark-ignition control system
- Air throttle
- Sensors/Switches/Speed inputs

The chart below lists the MI-07 components required for a G424F (E) engine operating on LP fuel.

Q'ty		DESCRIPTION
G424FE	G424F-LP	
1	1	Engine Control Module (SECM 48-pin)
0(LP) 1(DF)	0(LP)	Camshaft Position Sensor
1	1	Crankshaft Position Sensor
1	1	TMAP Sensor
1	None	Fuel Temperature Sensor
1	1	Transmission Oil Temperature Switch
2	None	Oxygen Sensors
1	1	Coolant Temperature Sensor
1	1	Engine Oil Pressure Switch
2	None	Fuel Trim Valve
1	1	Ignition Coils
1	1	Fuel Lock Off Solenoid
N-2007	N-2001	LP Regulator
CA-100 (Certified)	CA-100	LP Mixer
1	1	Electronic Throttle Body

Key Components

The MI-07 system functions primarily on engine components that affect engine emissions and performance. These key components include the following:

- Engine/Combustion chamber design
- Intake/Exhaust valve configuration, timing and lift
- Intake/Exhaust manifold design
- Catalytic converter and exhaust system
- Throttle body
- Air intake and air filter
- LPG mixer
- LPG pressure regulator
- Fuel trim valves
- Fuel trim orifices
- Small engine control module (SECM), firmware and calibration †
- Fuel system sensors and actuators
- Ignition system including spark plugs, cables, coils and drivers
- Gasoline injectors and fuel pressure regulator (dual-fuel systems only)

MI-07 System Features

The MI-07 system uses an advanced speed-density control strategy for fuel, spark, and air throttle control. Key features include the following.

- Closed-loop fuel control with fuel specific controls for LPG, and gasoline (MPI) fuels
- Speed-load spark control with tables for dwell, timing, and fuel type
- Speed-load throttle control with table for maximum TPS limiting
- Closed-loop fuel control with two oxygen sensors (one installed pre catalyst and one installed post catalyst). The pre-catalyst oxygen sensor includes adaptive learn to compensate for fuel or component drift. The post-catalyst oxygen sensor includes adaptive learn to compensate the pre-catalyst oxygen sensor setting for pre-catalyst oxygen sensor drift and catalyst aging. The pre-catalyst oxygen sensor function includes parameters for transport delay, O2 set point, excursion rich/lean, jump back rich/lean, and perturbation.
- LPG fuel temperature compensation
- Min/max governing
- All-speed isochronous governing
- Fixed-speed isochronous governing with three switch-selectable speeds
- Fuel enrichment and spark timing modifiers for temperature and fuel type
- Transient fuel enrichment based on rate of change of TPS
- Transient wall wetting compensation for gasoline
- Input sensor selection and calibration
- Auxiliary device control for fuel pump, fuel lock-off solenoid, tachometer, MIL, interlocks, vehicle speed limiting, etc.
- CANBus data transfer for speed, torque, etc.

Other system features include:

Tamper-Resistance
Special tools, equipment, knowledge, and authorization are required to effect any changes to the MI-07 system, thereby preventing unauthorized personnel from making adjustments that will affect performance or emissions.

Diagnostics
MI-07 is capable of monitoring and diagnosing problems and faults within the system. These include all sensor input hardware, control output hardware, and control functions such as closed-loop fuel control limits and adaptive learn limits. Upon detecting a fault condition, the system notifies the operator by illuminating the MIL and activating the appropriate fault action. The action required by each fault shall be programmable by the OEM customer at the time the engine is calibrated.

Diagnostic information can be communicated through both the service tool interface and the MIL lamp. With the MIL lamp, it is possible to generate a string of flashing codes that correspond to the fault type. These diagnostics are generated only when the engine is not running and the operator initiates a diagnostic request sequence such as repeated actuations of the pedal within a short period of time following reset.

Limp Home Mode
The system is capable of "limp-home" mode in the event of particular faults or failures in the system. In limp-home mode the engine speed is approximately 1000 rpm at no load. A variety of fault conditions can initiate limp-home mode. These fault conditions and resulting actions are determined during calibration and are OEM customer specific.

Service Tool
A scan tool/monitoring device is available to monitor system operation and assist in diagnosis of system faults This device monitors all sensor inputs, control outputs, and diagnostic functions in sufficient detail through a single access point to the SECM to allow a qualified service technician to maintain the system. This Mototune software (licensed by Mototron Communication) is secure and requires a crypt-token USB device to allow access to information.

LPG Fuel System Operation

The principles outlined below describe the operation of MI-07 on an LPG fuel system.

An LPG fuel system consists of the following components:
- Fuel filter
- Electric fuel lock-off solenoid valve
- Fuel pressure regulator/vaporizer
- Two orificed fuel trim valves
- Gas/Air mixer with fixed orifice for trim system and fuel temperature sensor
- Miscellaneous customer-supplied hoses and fittings

Fuel is stored in the customer-supplied LPG tank in saturated liquid phase and enters the fuel system from the tank as a liquid and at tank pressure. Fuel passes through a high-pressure fuel filter and lock-off solenoid, and is then vaporized and regulated down to the appropriate pressure to supply the mixer. The regulator controls the fuel pressure to the gas/air mixer.

Dual Dither Valve

The key to meeting emissions requirements when operating in LPG is the dual dither valve hardware in the fuel system. Similar to the MI-04 system, the dual dither system modulates the fuel pressure regulator outlet pressure by providing an offset to the regulator secondary stage reference pressure. By adding a second dither valve, or fuel trim valve (FTV), to the MI-07 system, smoother, more accurate control of supply pressure is achieved, resulting in better control of air fuel ratio and emissions. This smoother control also minimizes wear on fuel system components such as the regulator diaphragm and lever by significantly reducing the pressure pulsations observed with a single FTV.

Regulator Pressure Offset

Regulator pressure offset is achieved through the use of a fixed orifice and a variable orifice in series. The inlet to the fixed orifice is connected to the mixer inlet pressure (roughly equal to ambient pressure). The outlet of the fixed orifice is connected to both the pressure regulator reference port and the inlet to the two FTVs (the variable orifice) that act in parallel. The outlets of the FTVs are connected to the mixer outlet, referred to as Air Valve Vacuum (AVV). Thus, by modulating the FTVs, the pressure regulator reference pressure can be varied between mixer inlet pressure and AVV. For a given change in the pressure regulator reference pressure, the

pressure regulator outlet pressure changes by the same amount and in the same direction. The end result is that a change in FTV modulation changes the outlet pressure of the regulator/fuel inlet pressure of the mixer, and thus the AFR. A major benefit of this trim system results from the use of mixer inlet pressure and AVV as the reference pressure extremes. The pressure differential across the mixer fuel valve is related to these same two pressures, and thus so is fuel flow. Given this arrangement, the bias pressure delta scales with the fuel cone delta pressure. The result is that the trim system control authority and resolution on AFR stays relatively constant for the entire speed and load range of the engine.

SECM

The Small Engine Control Module (SECM) controls the LPG lock-off solenoid valve and the FTVs. The lock-off solenoid is energized when fueling with LPG and the engine is turning. FTV modulation frequency will be varied as a function of rpm by the SECM in order to avoid resonance phenomena in the fuel system. FTV commands will be altered by the SECM in order to maintain a stoichiometric air-fuel ratio. Commands are based primarily on feedback from the exhaust gas oxygen sensor, with an offset for fuel temperature.

MI-07 LP Fuel Filter

After exiting the fuel tank, liquid propane passes through a serviceable inline fuel filter to the electric fuel lock off. Figure 3 shows a typical inline type LP fuel filter manufactured by Century. The primary function of the fuel filter is to remove particles and sediments that have found their way into the tank. The LP fuel filter will not remove heavy end solids and paraffins that build up in LPG fuel systems as a result of vaporization.



Figure 3. Inline LP Fuel Filter

MI-07 Fuel Lock-Off (Electric)

The fuel lock-off is a safety shutoff valve, normally held closed by spring pressure, which is operated by an electric solenoid and prevents fuel flow to the regulator/ converter when the engine is not in operation. This is the first of three safety locks in the MI-07 system.

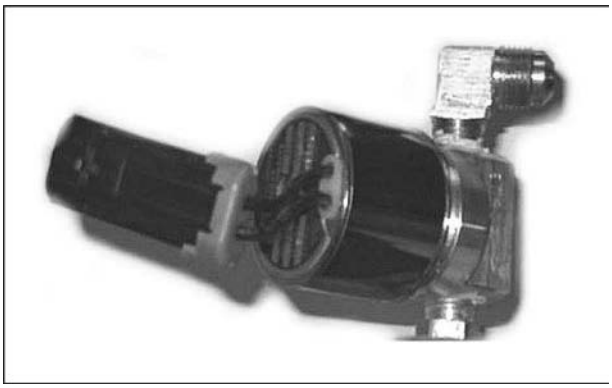


Figure 4. Electric Fuel Lock Assembly

In the MI-07 design, power is supplied to the fuel lock-off via the main power relay with the SECM controlling the lock-off ground (earth) connection. The lock-off remains in a normally closed (NC) position until the key switch is activated.
This supplies power to the lock-off and the SECM, but will not open the lock-off via the main power relay until the SECM provides the lock-off ground connection. This design gives the SECM full control of the lock-off while providing additional safety by closing the fuel lock-off in the unlikely event of a power failure, wiring failure or module failure.

When the liquid service valve in the fuel container is opened, liquid propane flows through the LP filter and through the service line to the fuel lock-off. Liquid propane enters the lock-off through the 1/4" NPT liquid inlet port and stops with the lock-off in the normally closed position. When the engine is cranked over the main power relay applies power to the lock-off and the SECM provides the lock-off ground causing current to flow through the windings of the solenoid creating a magnetic field. The strength of this magnetic field is sufficient to lift the lock-off valve off of its seat against spring pressure. When the valve is open liquid propane, at tank pressure, flows through the lock-off outlet to the pressure regulator/converter. A stall safety shutoff feature is built into the SECM to close the lock-off in case of a stall condition. The SECM monitors three engine states: Crank, when the crankshaft position sensor detects any engine revolutions; Stall, when the key is in the ON position but the crankshaft position sensor detects no engine revolutions; and the Run state, when the engine reaches pre-idle rpm.

When an operator turns on the key switch the lock-off is opened, but if the operator fails to crank the engine the SECM will close the lock-off after 5 seconds.

N-2007 Pressure Regulator/Vaporizer

The pressure regulator/vaporizer receives liquid LPG from the fuel storage tank, drops the pressure, changes the LPG phase from liquid to vapor, and provides vapor phase LPG at a regulated outlet pressure to the mixer. To offset the refrigeration effect of the vaporization process, the regulator will be supplied with engine coolant flow sufficient to offset the latent heat of vaporization of the LPG. A thermostat provided in the coolant supply line to maintain regulator outlet coolant temperature at or below 140oF (60°C) will minimize the deposit of fuel contaminants and heavy ends in the regulator and assure a more controlled vaporization process with reduced pressure pulsations.

A higher flow pressure regulator is required on larger engines.



Figure 5. N-2007 Regulator

The regulator is normally closed, requiring a vacuum signal (negative pressure) to allow fuel to flow. This is the second of three safety locks in the MI-07 system. If the engine stops, vacuum signal stops and fuel flow will automatically stop when both the secondary (2nd stage) valve and the primary (1st stage) valve closes. Unlike most other regulator/converters, the N-2007 primary valve closes with fuel pressure rather than against pressure, extending primary seat life and adding additional safety.

Liquid propane must be converted into a gaseous form in order to be used as a fuel for the engine. When the regulator receives the desired vacuum signal it allows propane to flow to the mixer. As the propane flows through the regulator the pressure is reduced in two stages from tank pressure to slightly less than atmospheric pressure. As the pressure of the propane is reduced, the liquid propane vaporizes and refrigeration occurs inside the regulator due to the vaporization of liquid propane. To replace heat lost to vaporization, engine coolant is supplied by the engine driven water pump and pumped through the regulator. Heat provided by this coolant is transferred through to the fuel vaporization chamber.

N-2007 Operation

(Refer to Figure 6.)
Liquid propane, at tank pressure, enters the N-2007 through the fuel inlet port (1). Propane liquid then flows through the primary valve (2). The primary valve located at the inlet of the expansion chamber (3), is controlled by the primary diaphragm (4), which reacts to vapor pressure inside the expansion chamber. Two springs are used to apply force on the primary diaphragm in the primary diaphragm chamber (5), keeping the primary valve open when no fuel pressure is present.

A small port connects the expansion chamber to the primary diaphragm chamber. At the outlet of the expansion chamber is the secondary valve (6). The secondary valve is held closed by the secondary spring on the secondary valve lever (7). The secondary diaphragm controls the secondary lever. When the pressure in the expansion chamber reaches 1.5 psig (10.3 kPa) it causes a pressure/force imbalance across the primary diaphragm (8). This force is greater than the primary diaphragm spring pressure and will cause the diaphragm to close the primary valve.

Since the fuel pressure has been reduced from tank pressure to 1.5 psig (10.3 kPa) the liquid propane vaporizes. As the propane vaporizes it takes on heat from the expansion chamber. This heat is replaced by engine coolant, which is pumped through the coolant passage of the regulator. At this point vapor propane will not flow past the expansion chamber of the regulator until the secondary valve is opened. To open the secondary valve, a negative pressure signal must be received from the air/fuel mixer. When the engine is cranking or running a negative pressure signal (vacuum) travels through the vapor fuel outlet connection of the regulator, which is the regulator secondary chamber, and the vapor fuel inlet of the mixer. The negative pressure in the secondary chamber causes a pressure/force imbalance on the secondary diaphragm, which overcomes the secondary spring force, opening the secondary valve and allowing vapor propane to flow out of the expansion chamber, through the secondary chamber to the mixer.

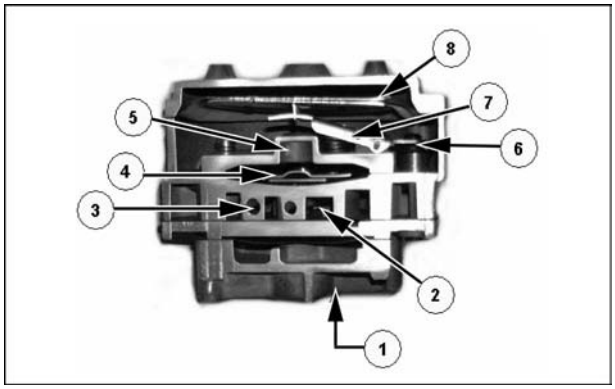


Figure 6. Parts View of N-2007 Regulator

Because vapor propane has now left the expansion chamber, the pressure in the chamber will drop, causing the primary diaphragm spring force to re-open the primary valve allowing liquid propane to enter the regulator, and the entire process starts again. This creates a balanced condition between the primary and secondary chambers allowing for a constant flow of fuel to the mixer as long as the demand from the engine is present. The fuel flow is maintained at a constant output pressure, due to the calibrated secondary spring. The amount of fuel flowing will vary depending on how far the secondary valve opens in response to the negative pressure signal generated by the air/fuel mixer. The strength of that negative pressure signal developed by the mixer is directly related to the amount of air flowing through the mixer into the engine. With this process, the larger the quantity of air flowing into the engine, the larger the amount of fuel flowing to the mixer.

CA100 Mixer

The mixer is installed above the throttle body and meters gaseous fuel into the airstream at a rate that is proportional to the volumetric flow rate of air. The ratio between volumetric airflow and volumetric fuel flow is controlled by the shaping of the mixer fuel cone and biased by the controllable fuel supply pressure delivered by the pressure regulator. Fuel flow must be metered accurately over the full range of airflows. Pressure drop across the mixer air valve must be minimized to assure maximum power output from the engine.

The mixer fuel inlet is fitted with a thermistor-type temperature sensor. This permits the SECM to correct fuel pressure to compensate for variations in fuel temperature. Left uncorrected, fuel temperature variations can cause significant variations in air fuel ratio.

A higher flow mixer is required on larger engines. A lower flow mixer is required on smaller engines.


Figure 7. CA100 Mixer

CA100 Mixer Operation

Vapor propane fuel is supplied to the CA100 mixer by the N-2007 pressure regulator/converter. The mixer uses a diaphragm type air valve assembly to operate a gas-metering valve inside the mixer. The gas-metering valve is normally closed, requiring a negative pressure (vacuum) signal from a cranking or running engine to open. This is the third of the three safety locks in the MI-07 system. If the engine stops or is turned off, the air valve assembly closes the gas-metering valve, stopping fuel flow past the mixer. The gas-metering valve controls the amount of fuel to be mixed with the incoming air at the proper ratio. The air/fuel mixture then travels past the throttle, through the intake manifold and into the engine cylinders where it is compressed, ignited and burned.


Figure 8. CA100 Mixer Attached to Throttle Body

(Refer to Figure 98.)
The air/fuel mixer is mounted in the intake air stream between the air cleaner and the throttle. The design of the main body incorporates a cylindrical bore or mixer bore, fuel inlet (1) and a gas discharge jet (2). In the center of the main body is the air valve assembly, which is made up of the air valve (3), the gas-metering valve (4), and air valve diaphragm (5)

and air valve spring (6). The gas-metering valve is permanently mounted to the air valve diaphragm assembly with a face seal mounted between the two parts.

When the engine is not running this face seal creates a barrier against the gas discharge jet, preventing fuel flow with the aid (downward force) of the air valve spring. When the engine is cranked over it begins to draw in air, creating a negative pressure signal. This negative pressure signal is transmitted through four vacuum ports in the air valve.

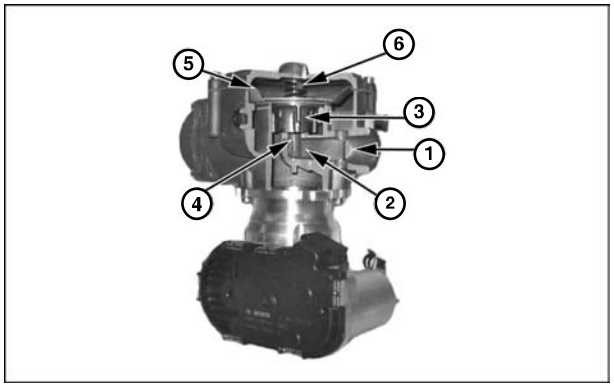


Figure 9. Parts View of CA100 Mixer

A pressure/force imbalance begins to build across the air valve diaphragm between the air valve vacuum (AVV) chamber (above the diaphragm) and atmospheric pressure below the diaphragm. Approximately 6 inH2O (14.945 mbar) of negative pressure is required to overcome the air valve spring force and push the air valve assembly upward off the valve seat. Approximately 24 inH2O (59.781 mbar) pulls the valve assembly to the top of its travel in the full open position.

The amount of negative pressure generated is a direct result of throttle position and the amount of air flowing through the mixer to the engine. At low engine speeds, low AVV causes the air valve diaphragm assembly to move upward a small amount, creating a small venturi. At high engine speeds, high AVV causes the air valve diaphragm assembly to move much farther creating a large venturi. The variable venturi air/fuel mixer constantly matches venturi size to engine demand.

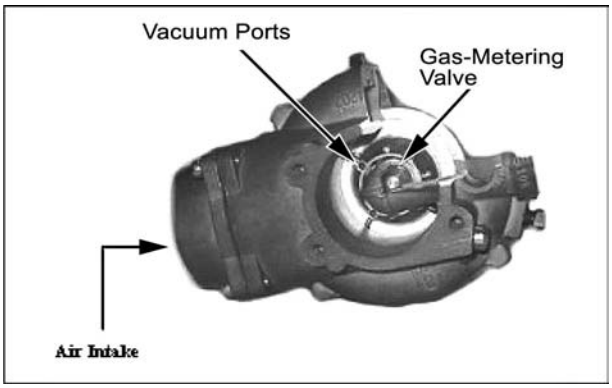


Figure 10. Bottom View of Air Valve Assembly


Figure 11. CA100 Mixer Installed with Electronic Throttle

A main mixture adjustment valve on the fuel inlet of the CA100 is not used in the MI-07 system, however an idle mixture adjustment is incorporated into the mixer (Figure 12). The idle mixture adjustment is an air bypass port, adjusting the screw all the way in, blocks off the port and enriches the idle mixture. Backing out the idle adjustment screw opens the port and leans the idle mixture. The idle mixture screw is a screw with locking threads that is factory set with a tamper proof cap installed after adjustment. Accurate adjustment of the idle mixture can be accomplished by adjusting for a specific fuel trim valve (FTV) duty cycle with the Service Tool software or with a voltmeter.

NOTE: Adjustments should only be performed by trained service technicians.

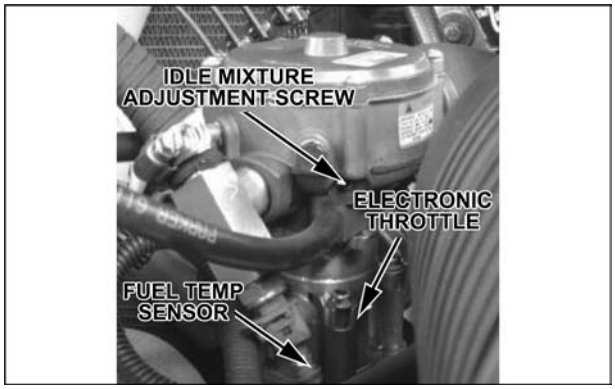


Figure 12. Idle Mixture Adjustment Screw (with tamper proof cap removed)

Fuel Trim Valve (FTV)



The Fuel Trim Valve (FTV) is a two-way electric solenoid valve and is controlled by a pulse-width modulated (PWM) signal provided by the SECM. Two FTVs are used to bias the output fuel pressure on the LPG regulator/converter (N-2007), by metering air valve vacuum (AVV) into the atmospheric side of the N-2007 secondary regulator diaphragm. An orifice balance line connected to the air inlet side of the mixer provides atmospheric reference to the N-2007 when the FTV is closed. The SECM uses feedback voltage from the O2 sensor to determine the amount of bias needed to the regulator/converter.

In normal operation the N-2007 maintains fuel flow at a constant output pressure, due to the calibrated secondary spring. The amount of fuel flowing from the N-2007 will vary depending on how far the secondary diaphragm opens the secondary valve in response to the negative pressure signal generated by the air/fuel mixer. One side of the N-2007 secondary diaphragm is referenced to FTV control pressure while the other side of the diaphragm reacts to the negative pressure signal from the mixer. If the pressure on the reference side of the N-2007 secondary diaphragm is reduced, the diaphragm will close the secondary valve until a balance condition exists across the diaphragm, reducing fuel flow and leaning the air/fuel mixture.

Branch-Tee Fitting

A branch-tee fitting is installed in the atmospheric vent port of the N-2007 with one side of the branch-tee connected to the intake side of the mixer forming the balance line and referencing atmospheric pressure. The other side of the branch-tee fitting connects to the FTV inlet (small housing side). The FTV outlet (large housing connector side) connects to the AVV port. When the FTVs are open AVV is sent to the atmospheric side of the N-2007 secondary diaphragm, which lowers the reference pressure, closing the N-2007 secondary valve and leaning the air/fuel mixture. The MI-07 system is calibrated to run rich without the FTV. By modulating (pulsing) the FTVs the SECM can control the amount of AVV applied to the N-2007 secondary diaphragm. Increasing the amount of time the FTVs remain open (modulation or duty cycle) causes the air/fuel mixture to become leaner; decreasing the modulation (duty cycle) enriches the mixture.

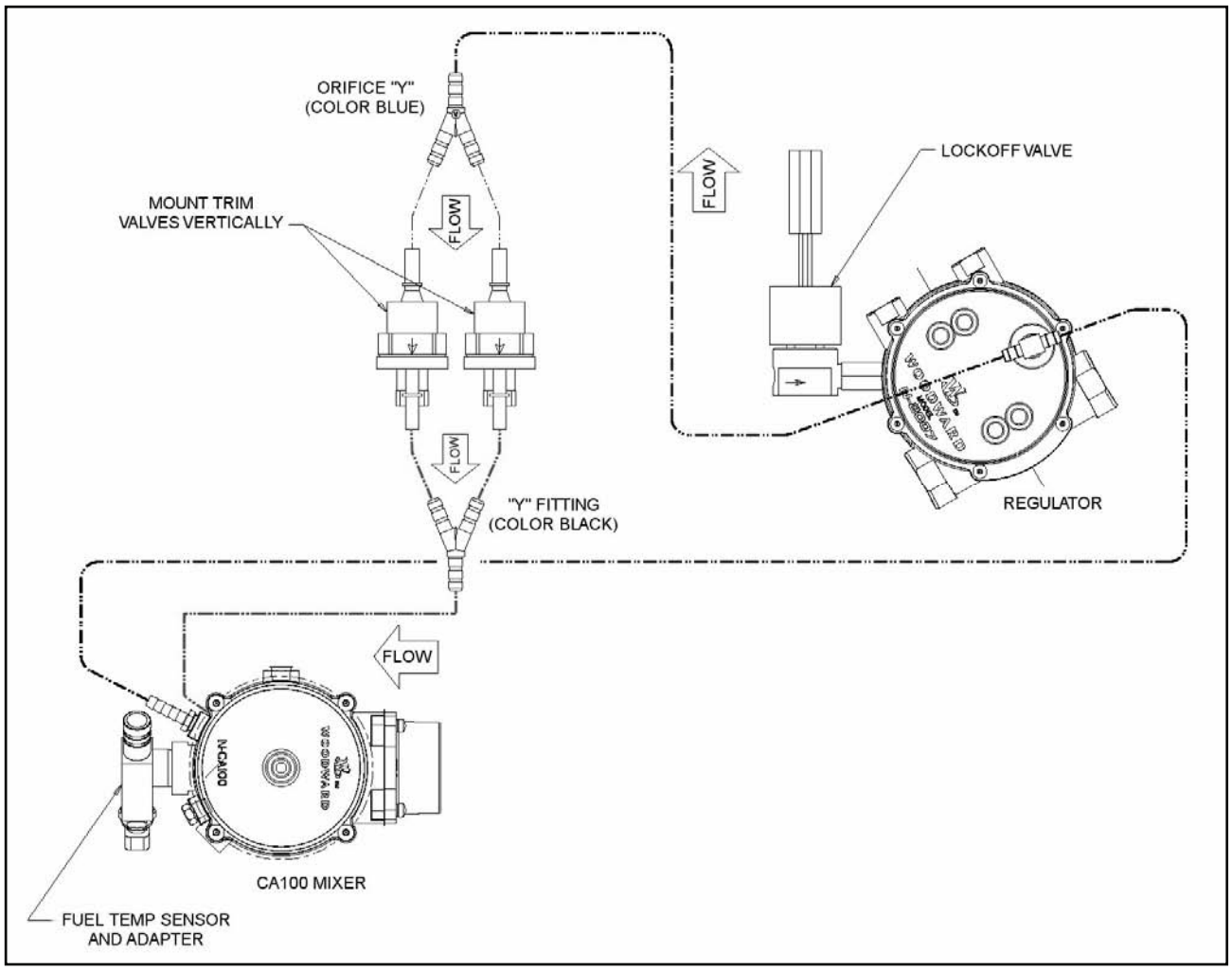
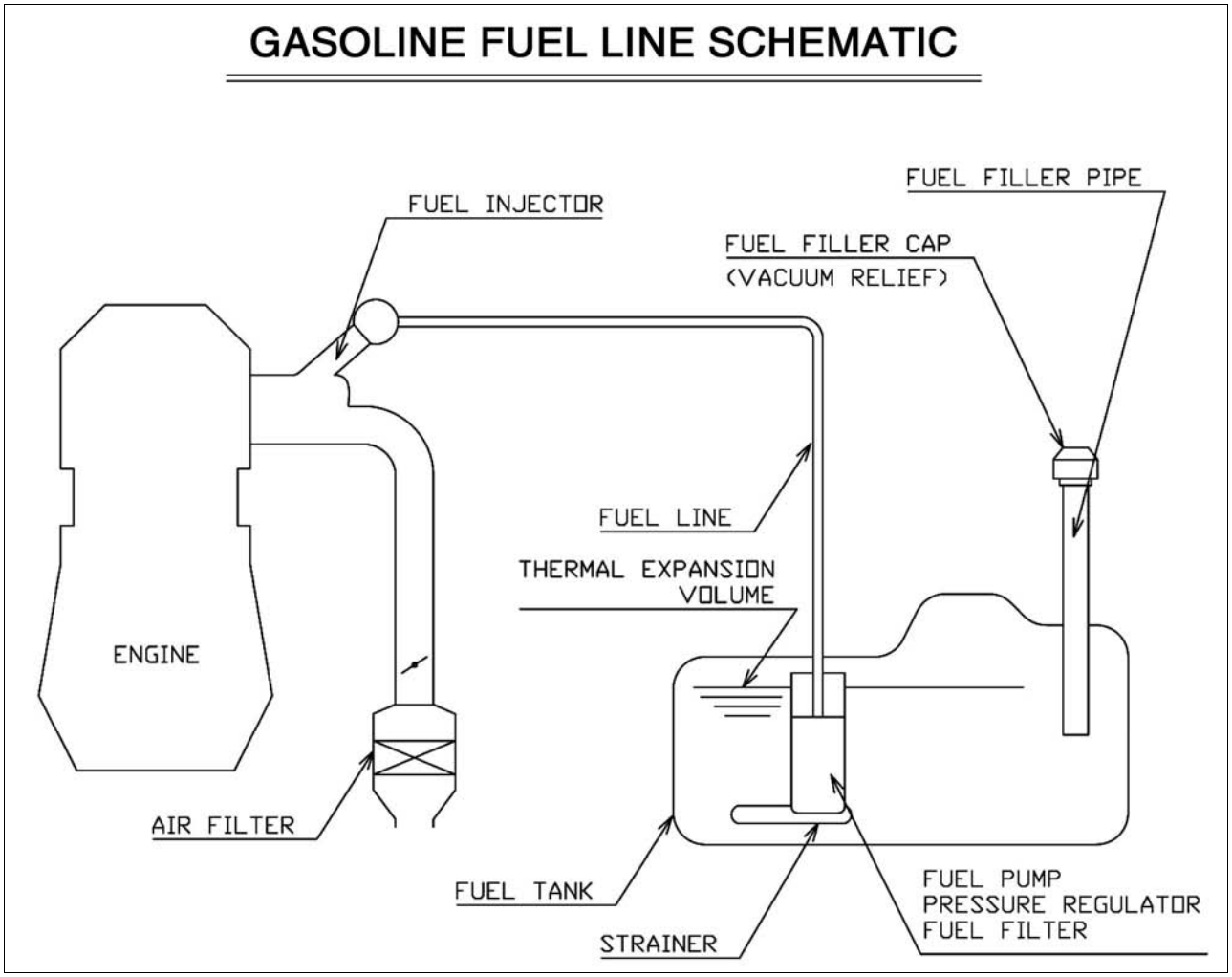


Figure 13. Fuel Trim Valves Connected to MI-07 System

MPI Gasoline System Operation

MPI (multi-point injection) system is used for G424FE dual fuel engine. An electric fuel pump in gasoline fuel tank supplies the fuel and generates the injection pressure. The gasoline fuel pressure regulator is a one-way, non-return configuration. All gasoline specific components are automotive production parts and validated to strict automotive standards. Four (4) sequential injection channels are supported. Injector as an electronic controlled fuel injection unit, is solenoid valve which supplies exactly calculated fuel as a spray to engine to best combustion under the condition of various engine load and speed.

For fuel consumption reduction, engine performance enhancement and emission reduction, ECM controls fuel injection to satisfy air fuel ratio required by system by reflecting induced airflow and air fuel ratio among emission and adjusting injector operating time. To enhance these control characteristics, quick response of injector is required, and spray feature of injector is important for perfect combustion.



Use of unleaded gasoline of 87 octane or higher is recommended for optimal performance of the MI-07 system.

A gasoline fuel system includes the following components:
Gasoline fuel pump
Fuel filter
Pressure regulator
Fuel rail
Fuel injectors
Small engine control module (SECM) and related sensors and equipment

Electronic Throttle System

The electronic throttle system controls engine output (speed and torque) through electronic control of mass airflow to the engine. Any DC motor-actuated or Limited Angle Torquemotor (LAT)-actuated throttle with less than 5A peak and 2A steady state can be controlled. The TPS must be directly coupled to the throttle shaft for direct shaft position measurement.

A commonly used throttle is the Bosch DV-E5. This throttle is available in a variety of bore sizes to meet specific engine needs: 32mm, 40mm, and 54mm are readily available throttle bore sizes; other sizes are possible. The Bosch throttle is a fully validated automotive component incorporating a brushed DC motor with gear reduction, dual throttle position sensors, throttle plate, and cast aluminum housing. In the event of an electrical disconnection or other related failure, the throttle plate returns to a limp-home idle position at a no-load engine speed above curb idle speed. This provides sufficient airflow for the engine to move the vehicle on level ground. Any throttle bodies used for MI-07 meet or exceed the specification for the Bosch throttle bodies.

In terms of response, the throttle is capable of fully opening and closing in less than 50 msec. Position resolution and steady state control should be 0.25% of full travel or better.

MI-07 Electronic Throttle

Conventional throttle systems rely on a mechanical linkage to control the throttle valve. To meet fluctuating engine demands a conventional system will typically include a throttle valve actuator designed to readjust the throttle opening in response to engine demand, together with an idle control actuator or idle air bypass valve.

In contrast, the MI-07 system uses electronic throttle control (ETC). The SECM controls the throttle valve based on engine RPM, engine load, and information received from the foot pedal. Two potentiometers on the foot pedal assembly monitor accelerator pedal travel. The electronic throttle used in the MI-07 system is a Bosch 32mm or 40mm electronic throttle body DV-E5 (Figure 14). The DV-E5 is a single unit assembly, which includes the throttle valve, throttle-valve actuator (DC motor) and two throttle position sensors (TPS). The SECM calculates the correct throttle valve opening that corresponds to the driver's demand, makes any adjustments needed for adaptation to the engine's current operating conditions and then generates a corresponding electrical (driver) signal to the throttle-valve actuator.



Figure 14. Bosch Electronic Throttle Body

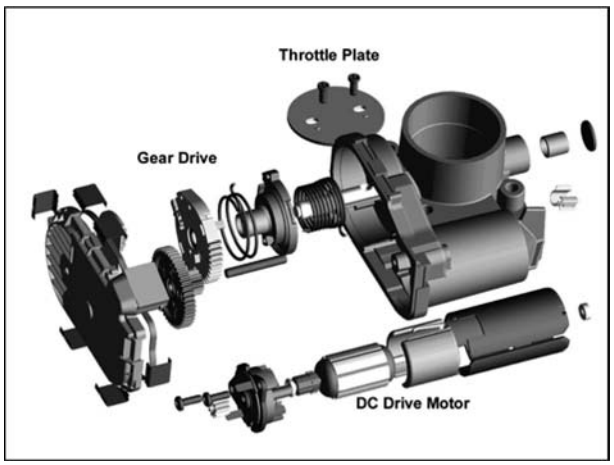
The MI-07 uses a dual TPS design (TPS1 and TPS2). The SECM continuously checks and monitors all sensors and calculations that effect throttle valve position whenever the engine is running. If any malfunctions are encountered, the SECM's initial response is to revert to redundant sensors and calculated data. If no redundant signal is available or calculated data cannot solve the malfunction, the SECM will drive the system into one of its limp-home modes or shut the engine down, storing the appropriate fault information in the SECM.

There are multiple limp-home modes available with electronic throttle control:

1. If the throttle itself is suspected of being inoperable, the SECM will remove the power to the throttle motor. When the power is removed, the throttle blade returns to its “default” position, approximately 7% open.

2. If the SECM can still control the throttle but some other part of the system is suspected of failure, the SECM will enter a “Reduced Power” mode. In this mode, the power output of the engine is limited by reducing the maximum throttle position allowed.

3. In some cases, the SECM will shut the engine down. This is accomplished by stopping ignition, turning off the fuel, and disabling the throttle.



Picture courtesy of Robert Bosch GmbH

Figure 15. Throttle Body Assembly Exploded View

Ignition System

Spark-ignited engines require accurate control of spark timing and spark energy for efficient combustion. The MI-07 ignition system provides this control. The system consists of the following components:

- SECM
- Ignition coil drivers *
- Ignition coil(s) *
- Crankshaft position sensor *
- Crankshaft timing wheel *
- Cam position sensor *
(sequential ignition or fuel injection only)
- Cam timing wheel *
(sequential ignition or fuel injection only)
- Spark plugs *

The SECM, through use of embedded control algorithms and calibration variables, determines the proper time to start energizing the coil and fire the spark plug. This requires accurate crank/camshaft position information, an engine speed calculation, coil energy information, and target spark timing. The SECM provides a TTL compatible signal for spark control. The coil must contain the driver circuitry necessary to energize the primary spark coil otherwise an intermediary coil driver device must be provided. The SECM controls spark energy (dwell time) and spark discharge timing.

Wasted Spark DIS Ignition System

The G424F and G424FE engine has a wasted spark ignition system (2 cylinders per coil).

Wasted spark ignition is a type of distributor-less ignition system where a pair of multi tower coils is mounted near the spark plugs. The DIS system eliminates the wear associated with most distributor type ignition systems. The wasted spark ignition fires pairs of cylinders at each ignition event. One cylinder fires on the compression stroke as is normal. However, the complementary pair in the firing order is fired simultaneously while that particular cylinder is on the exhaust stroke. Since the ionized exhaust gases require little spark energy, the majority of the ignition energy from the coil goes to the spark plug in the cylinder on the compression stroke.

The DIS coil pack can be mounted close to the spark plugs, thereby improving ignition lead routing

and length. There are fewer parts to malfunction on the DIS system when compared to a distributor type system.

DIS COMPONENTS

In a typical DIS ignition system, a crankshaft position sensor generates a basic timing signal by reading notches on the crankshaft, flywheel, or harmonic balancer. The crank sensor signal goes to the small engine control module (SECM), where it is used to determine firing order and turn the individual ignition coils on and off.

The operation of the ignition system is essentially the same as any other ignition system. Each coil has a low primary resistance (0.4 to 0.6 ohms) and steps up the primary system voltage from 12 volts to as much as 40,000 volts to produce a spark for the spark plug.

It is a direct connection that delivers the hottest spark possible. Resistor plugs are generally used to suppress electromagnetic interference (EMI).

MISFIRES

DIS problems can include many of the same ailments as other ignition systems such as misfiring, hard starting, or a no start. Spark plugs can still be fouled by oil or fuel deposits, as well as pre-ignition and detonation.

If the crankshaft position sensor fails, the loss of the basic timing signal will prevent the system from generating a spark and the engine will not start or run. A failed driver circuit within the SECM can kill individual coils and prevent two cylinders from firing.

It is important to remember that ignition misfire can also be caused by other factors such as worn or fouled spark plugs, loose or damaged coil connector or terminals, dirty fuel injectors, low fuel pressure, intake vacuum leaks, loss of compression in a cylinder, even contaminated fuel. These other possibilities should all be ruled out before a DIS unit is replaced.

A DIS engine that cranks but fails to start, in many cases, will often have a problem in the crankshaft or camshaft position sensor circuits. Loss of sensor signals may prevent the SECM from properly synchronizing, thereby preventing the engine from starting and running.

Exhaust System

Heated Exhaust Gas Oxygen Sensors (HEGO)

The MI-07 system utilizes two HEGO (O2) sensors. One sensor is a pre-catalyst sensor that detects the amount of oxygen in the exhaust stream and is considered the primary control point. Based upon the O2 sensor feedback, the MI-07 system supplies a stoichiometric air-fuel ratio to the catalytic converter. The catalytic converter then reduces emissions to the required levels. The second sensor is a post-catalyst sensor that detects the amount of oxygen after the catalyst. This sensor is used as a secondary control point to adjust the pre-catalyst setpoint to ensure proper catalyst conversion efficiency.



Figure 18. HEGO (O2) Sensor

Once a HEGO sensor reaches approximately 600°F (316°C), it becomes electrically active. The concentration of oxygen in the exhaust stream determines the voltage produced. If the engine is running rich, little oxygen will be present in the exhaust and voltage output will be relatively high. Conversely, in a lean situation, more oxygen will be present and a smaller electrical potential will be noticed.

In order for the sensor to become active and create an electrical signal below 600°F (316°C) a heated element is added to the sensor housing. Two wires provide the necessary 12 Vdc and ground signal for the heater element. A fourth wire provides an independent ground for the sensor. The pre-catalyst sensor heater is powered by the main power relay and is always powered. The post-catalyst sensor heater is powered from an additional relay that is controlled by the SECM. This relay is only energized when the SECM calculates that water condensation in the exhaust system and catalytic muffler prior to the sensor should be evaporated. This is to avoid thermal shock of the sensor that could prematurely fail the sensor.

The HEGO stoichiometric air-fuel ratio voltage target is approximately 500 mV and changes slightly as a function of speed and load. When the pre-catalyst HEGO sensor sends a voltage signal less than 450 mV the SECM interprets the air-fuel mixture as lean. The SECM then decreases the PWM duty cycle sent to the fuel trim valves in order to increase the fuel pressure to the mixer inlet; thus richening air-fuel mixture. The opposite is true if the SECM receives a voltage signal above 450 mV from the HEGO. The air-fuel mixture would then be interpreted as being too rich and the SECM would increase the duty cycle of the trim valves.

⚠ CAUTION

The HEGO sensors are calibrated to work with the MI-07 control system. Use of alternate sensors may impact performance and the ability of the system to diagnose rich and lean conditions.

Catalytic Muffler

In order to meet 2007 emission requirements a 3-way catalyst is necessary.

All exhaust gases pass through a catalyst that is mounted in the catalytic muffler. It filters the harmful gases through a dense honeycomb structure coated with precious metals such as platinum, palladium, and rhodium. Chemical reactions occur on these surfaces to convert the pollutants into less harmful gases. Catalysts store oxygen on lean mixtures (less than optimal amount of fuel) and release oxygen on rich mixtures (more than optimal amount of fuel). The primary pollutant produced on the lean swing is nitrous oxide. Oxygen is removed from nitrous oxide by the converter, resulting in nitrogen gas, a harmless emission. On the rich cycle, the primary pollutant is carbon monoxide. By adding the oxygen that was stored on the lean cycle to the carbon monoxide, carbon dioxide is produced.

Inside the catalytic muffler is a three-way catalyst as well as sound dampening and spark arresting features. The three-way catalyst section consists of a honeycomb coated with a mixture of platinum, palladium and rhodium. As engine exhaust gases flow through the converter passageways, they contact the coated surface, which initiate the catalytic process. The reduction catalyst is the first stage of the catalytic converter. It uses platinum and rhodium to help reduce the NOx emissions. The oxidation catalyst is the second stage of the catalytic converter. It reduces the unburned hydrocarbons and carbon monoxide by burning (oxidizing) them over a platinum and palladium catalyst. Cerium is also used to promote oxygen storage and improve oxidation efficiency.

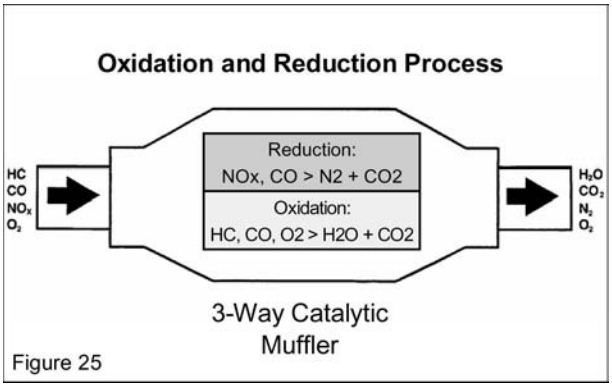
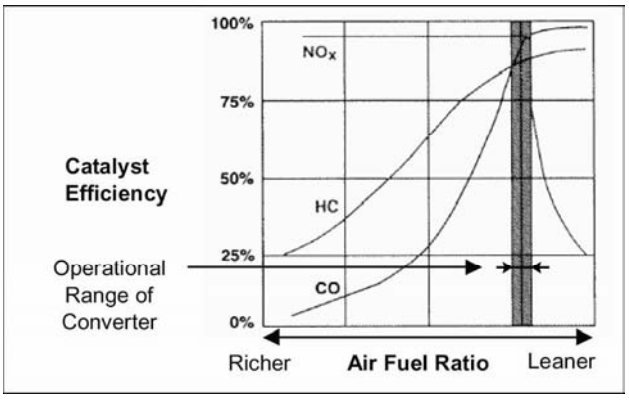


Figure 25

As exhaust and catalyst temperatures rise the following reaction occurs:

- Oxides of nitrogen (NOx) are reduced into simple nitrogen (N2) and carbon dioxide (CO2).
- Hydrocarbons (HC) and carbon monoxide (CO) are oxidized to create water (H2O) and carbon dioxide (CO2).



The MI-07 control system monitors the exhaust stream pre and post catalyst and uses this information to control the air-fuel mixture. By using the signals from the HEGOs, the SECM can increase or decrease the amount of oxygen in the exhaust by modulating the FTVs and adjusting the air-fuel ratio. This control scheme allows the SECM to make sure that the engine is running at the correct air to fuel ratio so that the catalyst can perform as required to meet the emissions certification.

SECM

General Description

The Small Engine Control Module (SECM) controller has full authority over spark, fuel and air. Utilizing a Freescale micro controller, the SECM has 48 pins of I/O and is fully waterproof and shock hardened. To optimize engine performance and drivability, the SECM uses several sensors for closed loop feedback information. These sensors are used by the SECM for closed loop control in three main categories:

- Fuel Management
- Load/Speed Management
- Ignition Management



The SECM monitors system parameters and stores any out of range conditions or malfunctions as faults in SECM memory. Engine run hours are also stored in memory. Stored fault codes can be displayed on the Malfunction Indicator Light (MIL) as flash codes or read by the MI-07 Service Tool software through a CAN (Controller Area Network) communication link.

Constant battery power (12 Vdc) is supplied through the fuse block to the SECM and the main power relays. Upon detecting a key-switch ON input, the SECM will fully power up and energize the main power relays.

The energized main power relays supply 12 Vdc power to the heated element of the oxygen sensors, fuel lock-off, fuel trim valves (FTVs), gasoline injectors, gasoline fuel pump, crank sensor, cam sensor, and the ignition coils.

The SECM supplies voltage to the electronic throttle actuator, oil pressure switch, fuel temperature sensor, and the coolant temperature sensor.

Transducer or sensor power (+ 5 Vdc) is regulated by the SECM and supplied to the manifold temperature/air pressure (TMAP) sensor, throttle position sensor (TPS), and the accelerator pedal position sensors (APP1 & APP2).

The SECM provides a transducer ground for all the sensors, and a low side driver signal controlling the fuel lock-off, MIL, gasoline injectors, gasoline fuel pump, and FTVs.

Fuel Management

During engine cranking at startup, the SECM provides a low side driver signal to the fuel lock-off, which opens the lock-off allowing liquid propane to flow to the N-2007 regulator. A stall safety shutoff feature is built into the SECM to close the lock-off in case of a stall condition. The SECM monitors three engine states:

Crank, when the crankshaft position sensor detects any engine revolutions

Stall, when the key is in the ON position but the crankshaft position sensor detects no engine revolutions

Run state, when the engine reaches pre-idle RPM.

When an operator turns on the key switch the lock-off is opened but if the operator fails to crank the engine, the SECM will close the lock-off after 5 seconds.

To maintain proper exhaust emission levels, the SECM uses a heated exhaust gas oxygen sensor (HEGO) mounted before the catalyst, to measure exhaust gas content in the LP gas system. Engine speed is monitored by the SECM through a variable reluctance (VR) sensor or Hall-Effect type sensor.

Intake manifold air temperature and absolute pressure are monitored with a (TMAP) sensor.

The HEGO voltage is converted to an air/fuel ratio value. This value is then compared to a target value in the SECM. The target value is based on optimizing catalyst efficiency for a given load and speed. The SECM then calculates any corrections that need to be made to the air/fuel ratio.

The system operates in open loop fuel control until the engine has done a certain amount of work.

This ensures that the engine and HEGO are sufficiently warmed up to stay in control. In open loop control, the FTV duty cycle is based on engine speed and load.

Once the HEGO reaches operating temperature the fuel management is in closed loop control for all steady state conditions, from idle through full throttle. In closed loop mode, the FTV duty cycle is based on feedback from the HEGO sensor. The system may return to open-loop operation when engine load or engine speed vary beyond a chosen threshold.

The SECM makes any necessary corrections to the air-fuel ratio by controlling the inlet fuel pressure to the air-fuel mixer Reducing the fuel pressure leans the air/fuel mixture and increasing the fuel pressure enriches the air-fuel mixture. Control is achieved by modulating the fuel trim valves.

Speed Management

Drive-by-wire refers to the fact that the MI-07 control system has no throttle cable from the foot pedal to the throttle body. Instead, the SECM is electronically connected both to the foot pedal assembly and the throttle body.

The SECM monitors the foot pedal position and controls the throttle plate by driving a DC motor connected to the throttle. The DC motor actuates the throttle plate to correspond to the foot pedal position when the operator depresses the pedal. The SECM will override the pedal command above a maximum engine speed and below a minimum idle speed.



Figure 19. Foot Pedal

The use of electronic throttle control (ETC) ensures that the engine receives only the correct amount of throttle opening for any given situation, greatly improving idle quality and drivability.

Two throttle position sensors (TPS1 and TPS2), which are integral to the drive-by-wire (DBW) throttle assembly, provide feedback for position control by monitoring the exact position of the throttle valve. See Figure 20.

SECM self-calibration and “cross checking” compares both signals and then checks for errors.

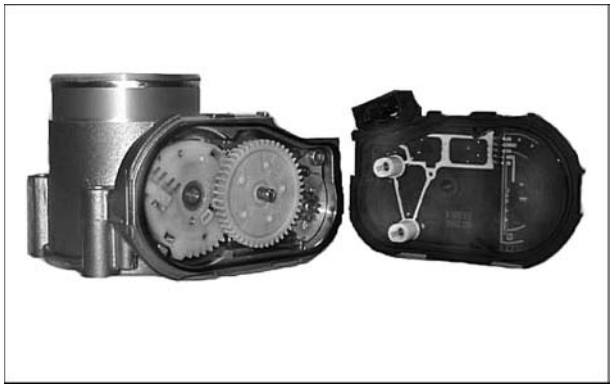


Figure 20. Throttle Position Sensor (TPS) on DV-E5 Throttle

NOTE : The DV-E5 throttle is not a serviceable assembly. If a TPS sensor fails, the assembly should be replaced.

The MI-07 system also performs minimum (min) and maximum (max) speed governing through the SECM and DBW throttle. For min governing, or idle speed control, the idle speed is fixed by the SECM. Unlike a mechanical system, the idle speed is not adjustable by the end user. The idle speed is adjusted by the SECM based on engine coolant temperature. At these low engine speeds, the SECM uses spark and throttle to maintain a constant speed regardless of load.

The MI-07 system eliminates the need for air velocity governors. This substantially increases the peak torque and power available for a given system as shown in Figure 21. When the engine speed reaches the max governing point the speed is controlled by closing the DBW throttle. Using the DBW throttle as the primary engine speed control allows for a smooth transition into and out of the governor. If excessive over speed is detected, the engine is shut down.

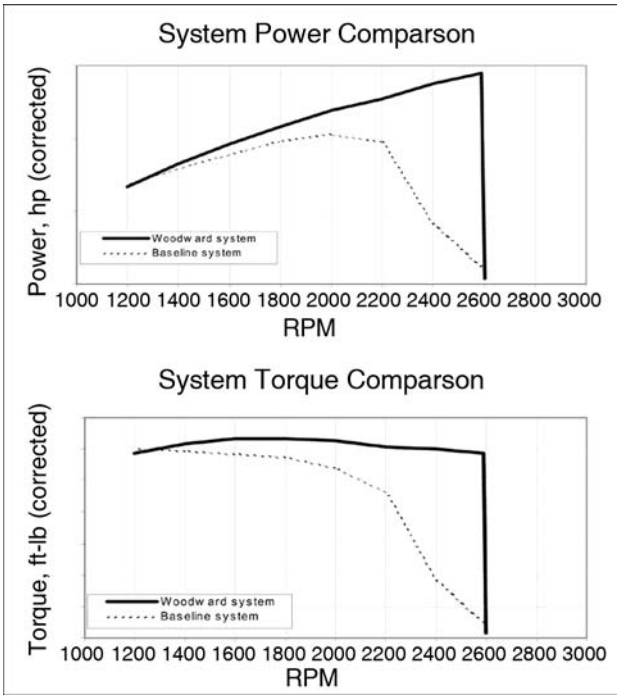


Figure 21. Peak Torque and Power Available with MI-07 System

Drive-By-Wire Signal Flow Process

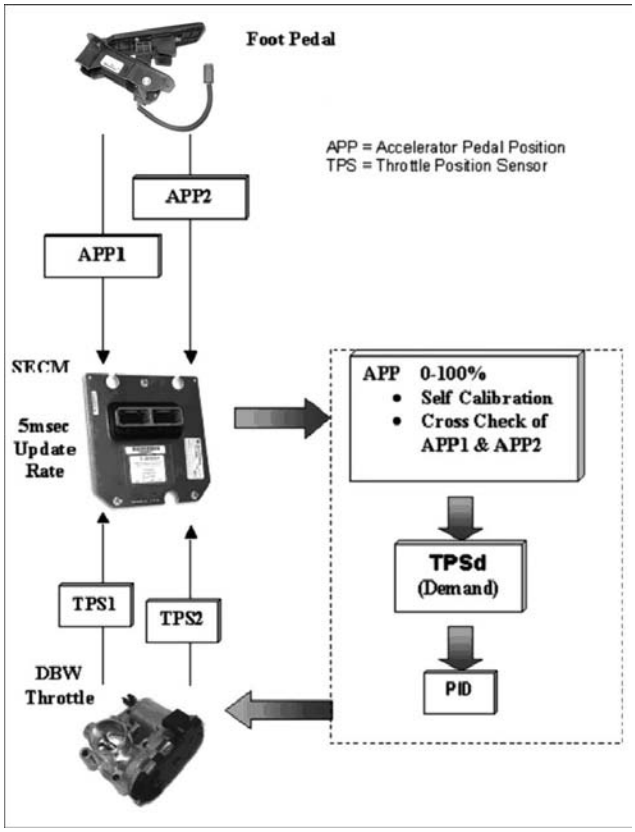


Figure 22. Drive-By-Wire Signal Flow Process

Figure 22 describes the signal flow process of the MI-07 DBW section. The foot pedal assembly uses two potentiometers to detect pedal position.
These two signals, accelerator pedal position 1 (APP1) and accelerator pedal position 2 (APP2) are sent directly to the SECM.
The SECM uses a series of algorithms to self calibrate and cross check the signals from the pedal assembly. A demand position for the throttle will then be derived and sent to the throttle as a throttle position sensor demand (TPSd). This signal will be processed through a PID (Proportional, Integral, Derivative) controller in the SECM to achieve the appropriate motor-current response then passed to the throttle. The throttle moves to the commanded position and provides a feedback signal from the throttle position sensors (TPS1 and TPS2) to the SECM.

Ignition Management

In the normal course of events, with the engine operating at the correct temperature in defined conditions, the SECM will use load and engine speed to derive the correct ignition timing. In addition to load and speed there are other circumstances under which the SECM may need to vary the ignition timing, including low engine coolant temperature, air temperature, start-up, and idle speed control.

SECM Electrical Mounting

Recommendations

In order to prevent the possibility of any SECM malfunctions due to EMI/RFI emissions, the SECM mounting and harness recommendations listed below:

- The SECM should be mounted in a location that minimizes the amount of EMI the module is exposed to by locating it as far as practical from all high tension components, such as ignition coils, distributors, spark plug wires, etc. It is recommended that the SECM be mounted at least 29.5” (749 mm) away from the distributor and ignition coil, and at least 20” (508 mm) from the nearest plug wire.
- All wiring harnesses should be routed to minimize coupling (both radiated and conducted), and be securely fastened to minimize movement and maintain proper clearance between the SECM and all ignition system components.
- The OEM must ensure that a high-quality ground connection between the SECM and battery negative (–) is provided and can be maintained for the useful life of the vehicle. This may require the use of star-type washers on all ground lug connections between the SECM and the battery and/or special preparation of all mating surfaces that complete the ground connection in order to ensure that the connection is sound.

SECM Wiring Diagrams for G424FE

⚠ CAUTION—PROPER WIRING

To prevent system faults be sure to follow good wiring practices. Poor wiring may cause unexpected or intermittent failures not related to MI-07 components.

The schematics on the next pages are wiring diagrams for G424FE engines.

Figure 21: Dual fuel certified system

Figure 22: LP certified system

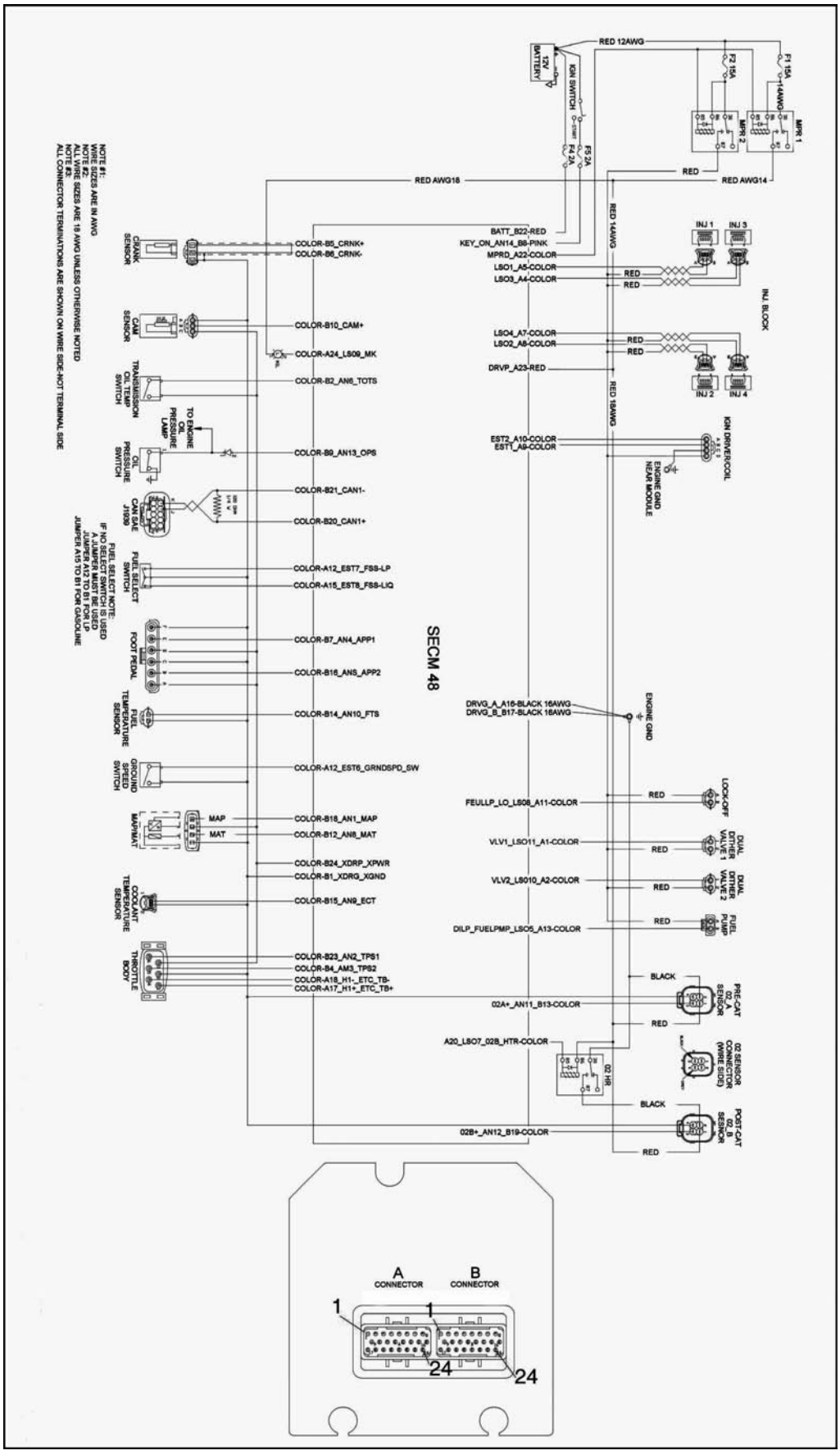


Figure 21. SECM Wiring Diagram for G424FE Dual Fuel System.

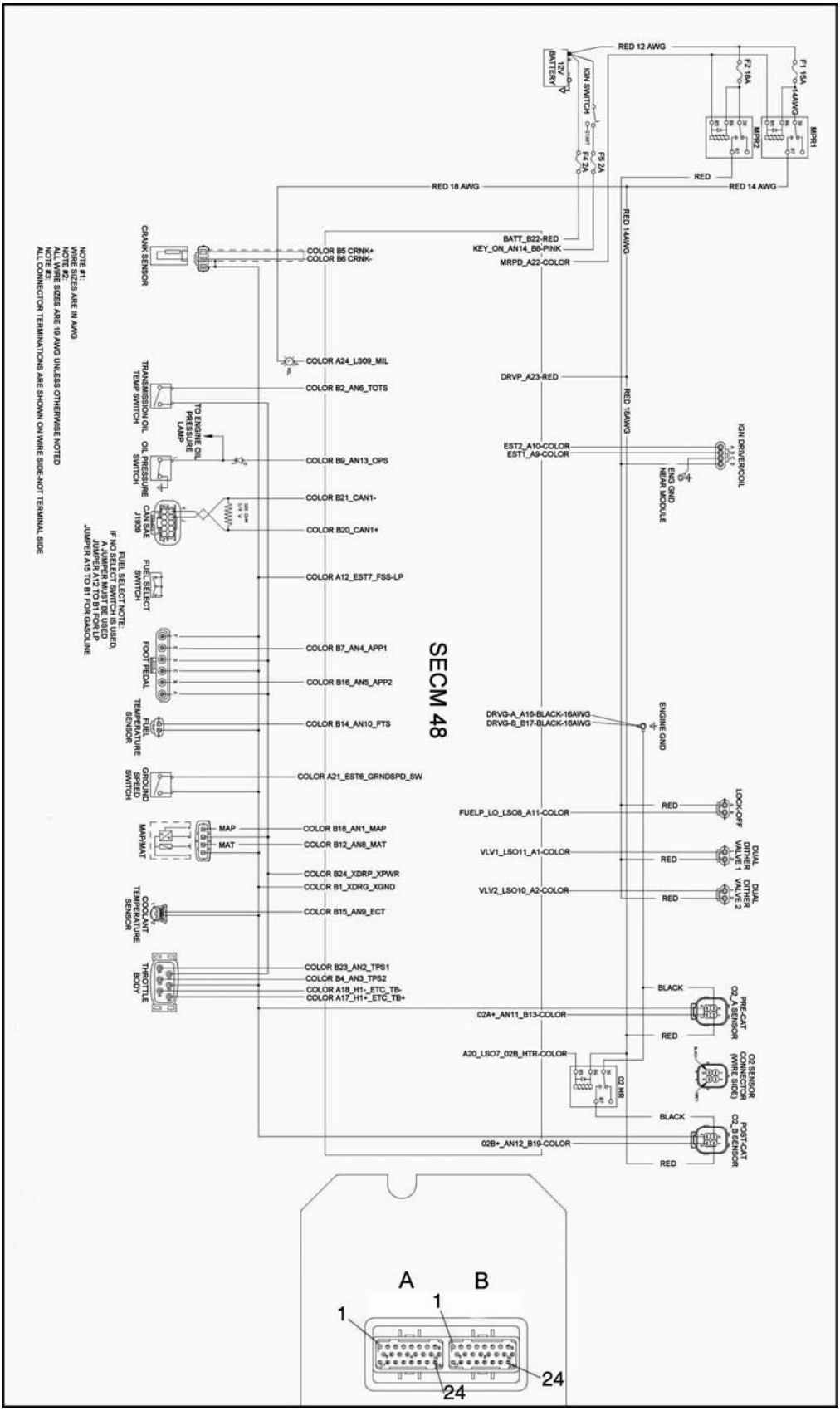


Figure 22. SECM Wiring Diagram for G424FE LP System.

G424F EMS (Engine Management System) Overview

General Description

MI-07 control system provides a complete, fully integrated engine management system for naturally aspirated engines.

It provides accurate, reliable, and durable control of spark and air over the service life of the engine in the extreme operating environment found in heavy-duty, under hood, on-engine electronic controls.

The SECM monitors the engine through a number of different sensors to ensure optimal performance. Engine speed is monitored by the SECM through a variable reluctance (VR) sensor. Intake manifold air temperature and absolute pressure are monitored with a TMAP sensor. MI-07 is a drive-by-wire (DBW) system connecting the accelerator pedal to the electronic throttle through the electrical harness; mechanical cables are not used. A throttle position sensor (TPS) monitors throttle position in relation to the accelerator pedal position sensor (APP) command. Even engine coolant temperature and adequate oil pressure are monitored by the SECM

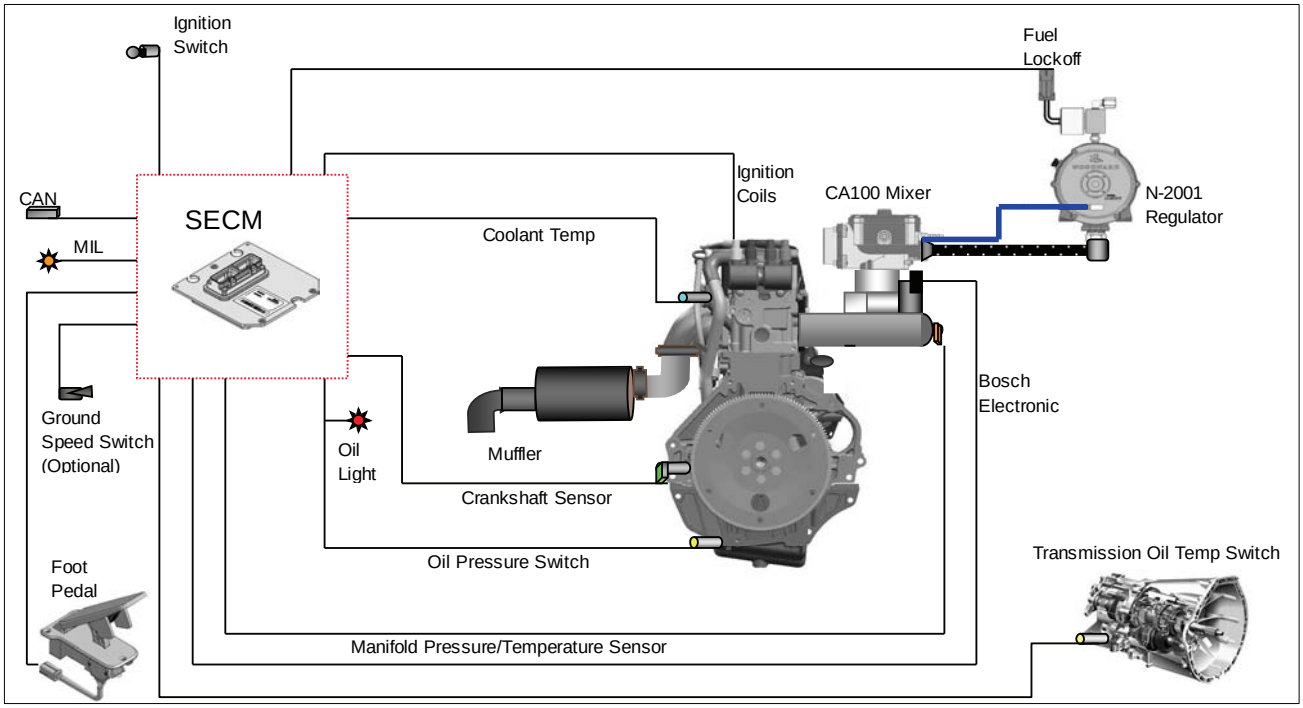
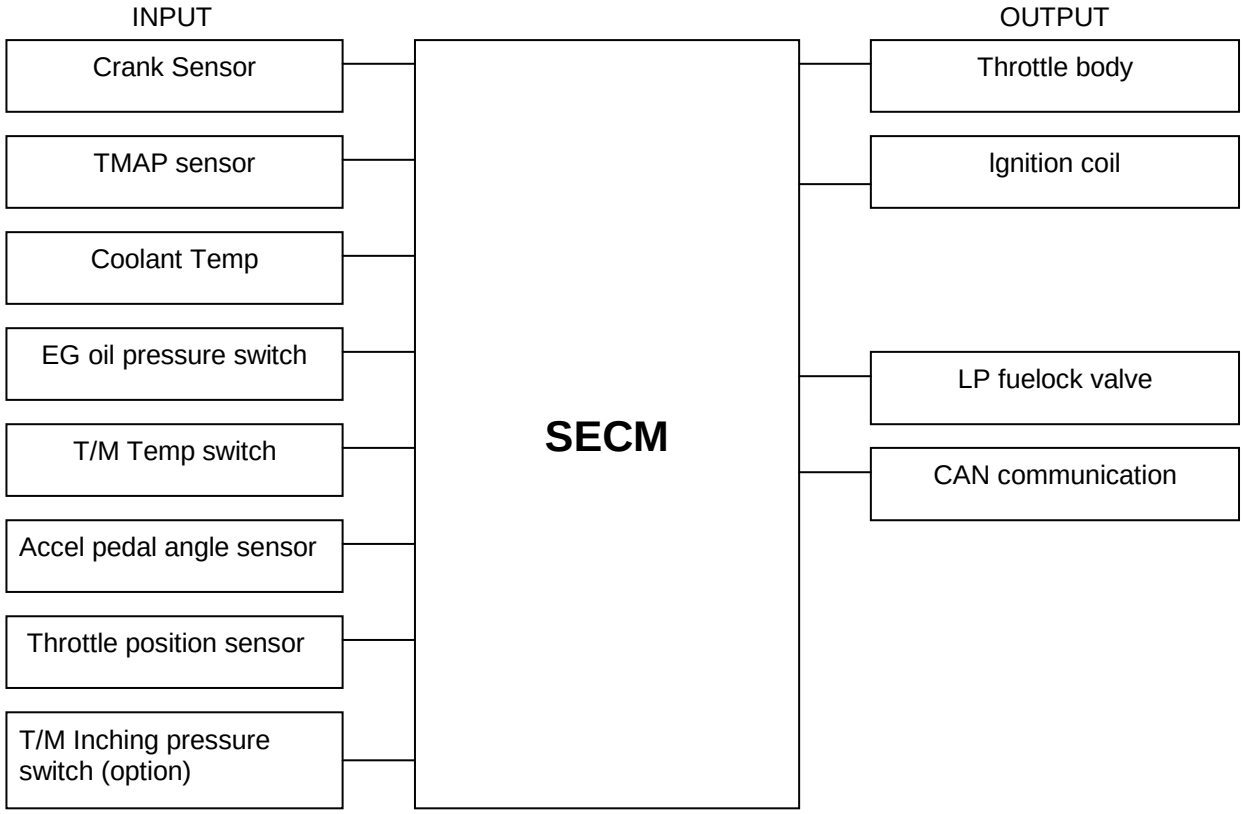


Figure 2. G424F LP System

The LPG regulator and the mixer operate as an open loop system since no mixture adjustments are made by the SECM. The mixer does have an idle mixture adjustment and a power valve adjustment. Manifold pressure from the TMAP, rpm from the crank position sensor and throttle position is used by the SECM to calculate load. Feedback from the electronic throttle is provided to the SECM by the throttle position sensors (TPS).

LP System of G424F



MI-07 System Components

The MI-07 control system provides electronic control to the following subsystems on mobile industrial engines:

- Fuel delivery system
- Spark-ignition control system
- Air throttle
- Sensors/Switches/Speed inputs

The chart below lists the MI-07 components required for a G424F engine operating on LP fuel.

Key Components

The MI-07 system functions primarily on engine components that affect engine

emissions and performance. These key components include the following:

- Engine/Combustion chamber design
- Intake/Exhaust valve configuration, timing and lift
- Intake/Exhaust manifold design
- Throttle body
- Air intake and air filter
- LPG mixer
- LPG pressure regulator
- Small engine control module (SECM), firmware and calibration †
- Fuel system sensors and actuators
- Ignition system including spark plugs, cables, coils and drivers

Q'ty		DESCRIPTION
G424FE -LP	**G424F -LP**	
1	1	Engine Control Module (SECM 48-pin)
None	None	Camshaft Position Sensor
1	1	Crankshaft Position Sensor
1	1	TMAP Sensor
1	None	Fuel Temperature Sensor
1	1	Transmission Oil Temperature Switch
2	None	Oxygen Sensors
1	1	Coolant Temperature Sensor
1	1	Engine Oil Pressure Switch
2	None	Fuel Trim Valve
1	1	Ignition Coils
1	1	Fuel Lock Off Solenoid
N-2007	N-2001	LP Regulator
CA-100 (Certified)	CA-100	LP Mixer
1	1	Electronic Throttle Body

MI-07 System Features

The MI-07 system uses an advanced speed-density control strategy for fuel, spark, and air throttle control. Key features include the following.

- Open-loop fuel control with fuel specific controls for LPG
- Speed-load spark control with tables for dwell, timing, and fuel type
- Speed-load throttle control with table for maximum TPS limiting
- Min/max governing
- All-speed isochronous governing
- Fixed-speed isochronous governing with three switch-selectable speeds
- Spark timing modifiers for temperature and fuel type
- Input sensor selection and calibration
- Auxiliary device control for fuel pump, fuel lock-off solenoid, tachometer, MIL, interlocks, vehicle speed limiting, etc.
- CANBus data transfer for speed, torque, etc.

Other system features include:

Tamper-Resistance
Special tools, equipment, knowledge, and authorization are required to effect any changes to the MI-07 system, thereby preventing unauthorized personnel from making adjustments that will affect performance or emissions.

Diagnostics
MI-07 is capable of monitoring and diagnosing problems and faults within the system. These include all sensor input hardware, control output hardware, and control functions such as closed-loop fuel control limits and adaptive learn limits. Upon detecting a fault condition, the system notifies the operator by illuminating the MIL and activating the appropriate fault action. The action required by each fault shall be programmable by the OEM customer at the time the engine is calibrated.

Diagnostic information can be communicated through both the service tool interface and the MIL lamp. With the MIL lamp, it is possible to generate a string of flashing codes that correspond to the fault type. These diagnostics are generated only when the engine is not running and the operator initiates a diagnostic request sequence such as repeated actuations of the pedal within a short period of time following reset.

Limp Home Mode
The system is capable of "limp-home" mode in the event of particular faults or failures in the system. In limp-home mode the engine speed is approximately 1000 rpm at no load. A variety of fault conditions can initiate limp-home mode. These fault conditions and resulting actions are determined during calibration and are OEM customer specific.

Service Tool
A scan tool/monitoring device is available to monitor system operation and assist in diagnosis of system faults This device monitors all sensor inputs, control outputs, and diagnostic functions in sufficient detail through a single access point to the SECM to allow a qualified service technician to maintain the system. This Mototune software (licensed by Mototron Communication) is secure and requires a crypt-token USB device to allow access to information.

LPG Fuel System Operation

The principles outlined below describe the operation of MI-07 on an LPG fuel system.

An LPG fuel system consists of the following components:

- Fuel filter (supplied by customer)
- Electric fuel lock-off solenoid valve
- Fuel pressure regulator/vaporizer
- Gas/Air mixer
- Miscellaneous customer-supplied hoses and fittings

Fuel is stored in the customer-supplied LPG tank in saturated liquid phase and enters the fuel system from the tank as a liquid and at tank pressure. Fuel passes through a high-pressure fuel filter and lock-off solenoid, and is then vaporized and regulated down to the appropriate pressure to supply the mixer. The regulator controls the fuel pressure to the gas/air mixer. The mixer meters fuel delivery based upon airflow into the engine.

SECM

The Small Engine Control Module (SECM) controls the LPG lock-off solenoid valve. The lock-off solenoid is energized when fueling with LPG and the engine is turning. The lock-off is de-energized when engine rpm is not detected.

MI-07 LP Fuel Filter

The LP fuel filter of G42F engine is the same as that of G424FE engine. See, “G424FE EMS overview”

MI-07 Fuel Lock-Off (Electric)

The LP fuel lock-off of G42F engine is the same as that of G42FE engine. See, “G424FE EMS overview”

N-2001 Regulator/Converter

After passing through the electric fuel lock-off, liquid propane enters the N-2001 regulator/converter (Figure 4). The N-2001 functions as a fuel vaporizer, converting liquid propane to vapor propane and as a two-stage negative pressure regulator, supplying the correct vapor propane fuel pressure to the mixer.

The regulator is normally closed requiring a vacuum signal (negative pressure) to allow fuel to flow. This is the second of three safety locks in the MI-07 system. If the engine stops, vacuum signal stops and fuel flow will automatically stop when both the secondary (2nd stage) valve and the primary (1st

stage) valve closes. Unlike most other regulator/converters, the N-2001 primary valve closes with fuel pressure rather than against pressure, extending primary seat life and adding additional safety.



Figure 4. N-2001 Regulator

Liquid propane must be converted into a gaseous form in order to be used as a fuel for the engine. When the regulator receives the desired vacuum signal it allows propane to flow to the mixer. As the propane flows through the regulator the pressure is reduced in two stages from tank pressure to slightly less than atmospheric pressure. As the pressure of the propane is reduced the liquid propane vaporizes and refrigeration occurs inside the regulator due to the large temperature drop inside the regulator from the vaporization of liquid propane. To replace heat lost to vaporization, engine coolant is supplied by the engine driven water pump and pumped through the regulator. Heat provided by this coolant is transferred through to the fuel vaporization chamber. Figure 5 shows the heat chamber and the coolant passage in the N-2001 regulator.

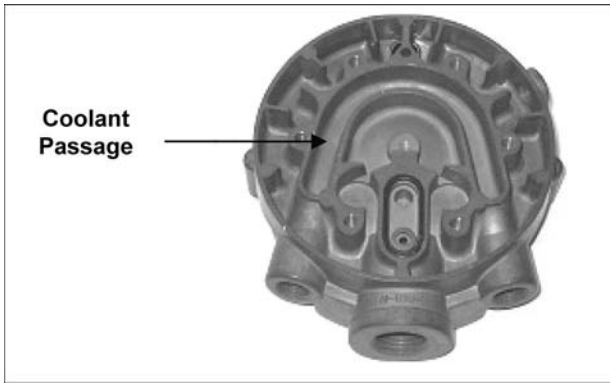


Figure 5. Heat Chamber and Coolant Passage

N-2001 Operation

Refer to Figure 6.
Liquid propane, at tank pressure, enters the N-2001 through the fuel inlet port (1). Propane liquid then flows through the primary valve (2). The primary valve located at the inlet of the expansion chamber (3), is controlled by the primary diaphragm (4), which reacts to vapor pressure inside the expansion chamber. Two springs are used to apply force on the primary diaphragm in the primary diaphragm chamber (5), keeping the primary valve open when no fuel pressure is present.

A small port connects the expansion chamber to the primary diaphragm chamber. At the outlet of the expansion chamber is the secondary valve (6). The secondary valve is held closed by the secondary spring on the secondary valve lever (7). The secondary diaphragm controls the secondary lever.
When the pressure in the expansion chamber reaches 1.5 psi (10.342 kPa it causes a pressure/ force imbalance across the primary diaphragm (8).
This force is greater than the primary diaphragm spring pressure and will cause the diaphragm to close the primary valve.

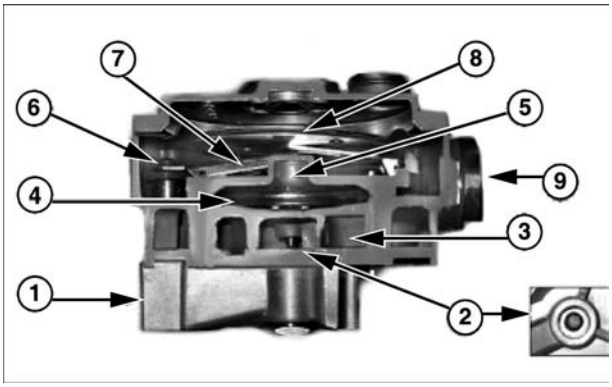


Figure 6. Parts View of N-2001 Regulator

Since the fuel pressure has been reduced from tank pressure to 1.5 psi (10.342 kPa) the liquid propane vaporizes. As the propane vaporizes it takes on heat from the expansion chamber. This heat is replaced by engine coolant, which is pumped through the coolant passage of the regulator. At this point vapor propane will not flow past the expansion chamber of the regulator until the secondary valve is opened.
To open the secondary valve a negative pressure signal must be received from the air/fuel mixer. When the engine is cranking or running a negative pressure signal (vacuum) travels through the vapor fuel outlet connection of the regulator (9), which is the regulator secondary chamber, and the vapor fuel inlet of the mixer. The negative pressure in the secondary chamber causes a pressure/force

imbalance on the secondary diaphragm, which overcomes the secondary spring force, opening the secondary valve and allowing vapor propane to flow out of the expansion chamber, through the secondary chamber to the mixer.

Because vapor propane has now left the expansion chamber, the pressure in the chamber will drop, causing the primary diaphragm spring force to re-open the primary valve allowing liquid propane to enter the regulator, and the entire process starts again. This creates a balanced condition between the primary and secondary chambers allowing for a constant flow of fuel to the mixer as long as the demand from the engine is present. The fuel flow is maintained at a constant output pressure, due to the calibrated secondary spring. The amount of fuel flowing will vary depending on how far the secondary valve opens in response to the negative pressure signal generated by the air/fuel mixer. The strength of that negative pressure signal developed by the mixer is directly related to the amount of air flowing through the mixer into the engine. With this process, the larger the quantity of air flowing into the engine, the larger the amount of fuel flowing to the mixer.

CA100 Mixer

The mixer is installed above the throttle body and meters gaseous fuel into the airstream at a rate that is proportional to the volumetric flow rate of air. The ratio between volumetric airflow and volumetric fuel flow is controlled by the shaping of the mixer fuel cone and biased by the controllable fuel supply pressure delivered by the pressure regulator. Fuel flow must be metered accurately over the full range of airflows. Pressure drop across the mixer air valve must be minimized to assure maximum power output from the engine.

A higher flow mixer is required on larger engines. A lower flow mixer is required on smaller engines.



Figure 7. CA100 Mixer

CA100 Mixer Operation

Vapor propane fuel is supplied to the CA100 mixer by the N-2001 pressure regulator/converter. The mixer uses a diaphragm type air valve assembly to operate a gas-metering valve inside the mixer. The gas-metering valve is normally closed, requiring a negative pressure (vacuum) signal from a cranking or running engine to open. This is the third of the three safety locks in the MI-07 system. If the engine stops or is turned off, the air valve assembly closes the gas-metering valve, stopping fuel flow past the mixer. The gas-metering valve controls the amount of fuel to be mixed with the incoming air at the proper ratio. The air/fuel mixture then travels past the throttle, through the intake manifold and into the engine cylinders where it is compressed, ignited and burned.



Figure 8. CA100 Mixer Attached to Throttle Body

(Refer **to Figure 98**.)
The air/fuel mixer is mounted in the intake air stream between the air cleaner and the throttle. The design of the main body incorporates a cylindrical bore or mixer bore, fuel inlet (1) and a gas discharge jet (2). In the center of the main body is the air valve assembly, which is made up of the air valve (3), the gas-metering valve (4), and air valve diaphragm (5) and air valve spring (6). The gas-metering valve is permanently mounted to the air valve diaphragm assembly with a face seal mounted between the two parts.

When the engine is not running this face seal creates a barrier against the gas discharge jet, preventing fuel flow with the aid (downward force) of the air valve spring. When the engine is cranked over it begins to draw in air, creating a negative pressure signal. This negative pressure signal is transmitted through four vacuum ports in the air valve.

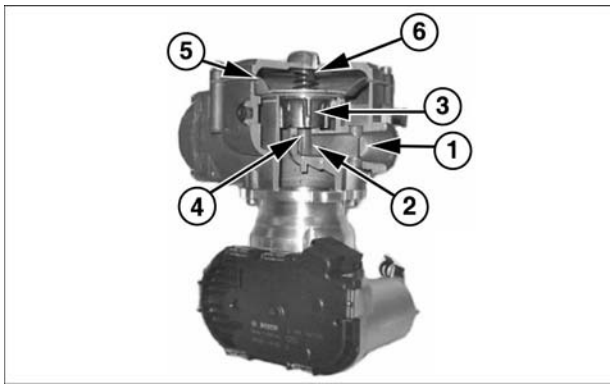


Figure 9. Parts View of CA100 Mixer

A pressure/force imbalance begins to build across the air valve diaphragm between the air valve vacuum (AVV) chamber (above the diaphragm) and atmospheric pressure below the diaphragm. Approximately 6 inH2O (14.945 mbar) of negative pressure is required to overcome the air valve spring force and push the air valve assembly upward off the valve seat. Approximately 24 inH2O (59.781 mbar) pulls the valve assembly to the top of its travel in the full open position.

The amount of negative pressure generated is a direct result of throttle position and the amount of air flowing through the mixer to the engine. At low engine speeds, low AVV causes the air valve diaphragm assembly to move upward a small amount, creating a small venturi. At high engine speeds, high AVV causes the air valve diaphragm assembly to move much farther creating a large venturi. The variable venturi air/fuel mixer constantly matches venturi size to engine demand.

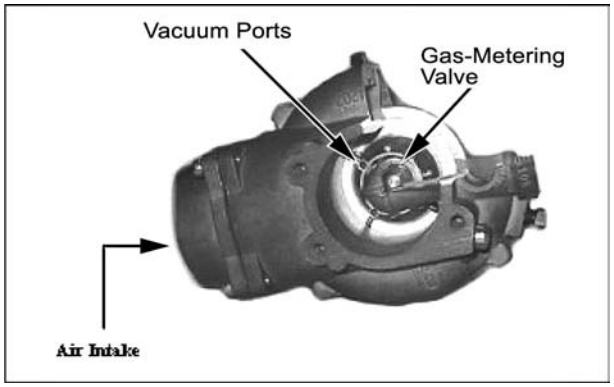
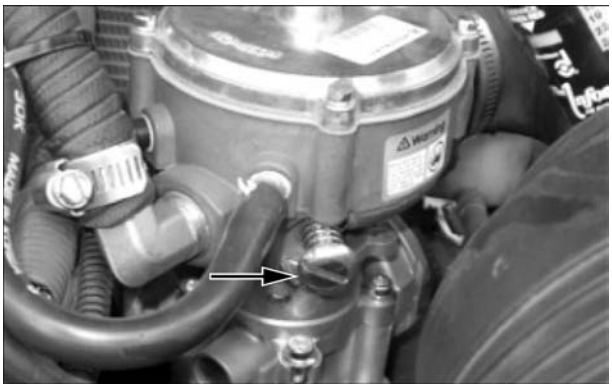


Figure 10. Bottom View of Air Valve Assembly


Figure 11. CA100 Mixer Installed with Electronic Throttle

A main mixture adjustment valve on the fuel inlet of the CA100 is not used in the MI-07 system, however an idle mixture adjustment is incorporated into the mixer (Figure 12). The idle mixture adjustment is an air bypass port, adjusting the screw all the way in, blocks off the port and enriches the idle mixture. Backing out the idle adjustment screw opens the port and leans the idle mixture. The idle mixture screw is a screw with locking threads that is factory set with a tamper proof cap installed after adjustment. Accurate adjustment of the idle mixture can be accomplished by adjusting for a specific fuel trim valve (FTV) duty cycle with the Service Tool software or with a voltmeter.

NOTE: Adjustments should only be performed by trained service technicians.


Figure 12. Idle Mixture Adjustment Screw

Electronic Throttle System

The electronic throttle system of G424F engine is the same as that of G424FE engine. See, “Electronic throttle system of G424FE EMS overview”

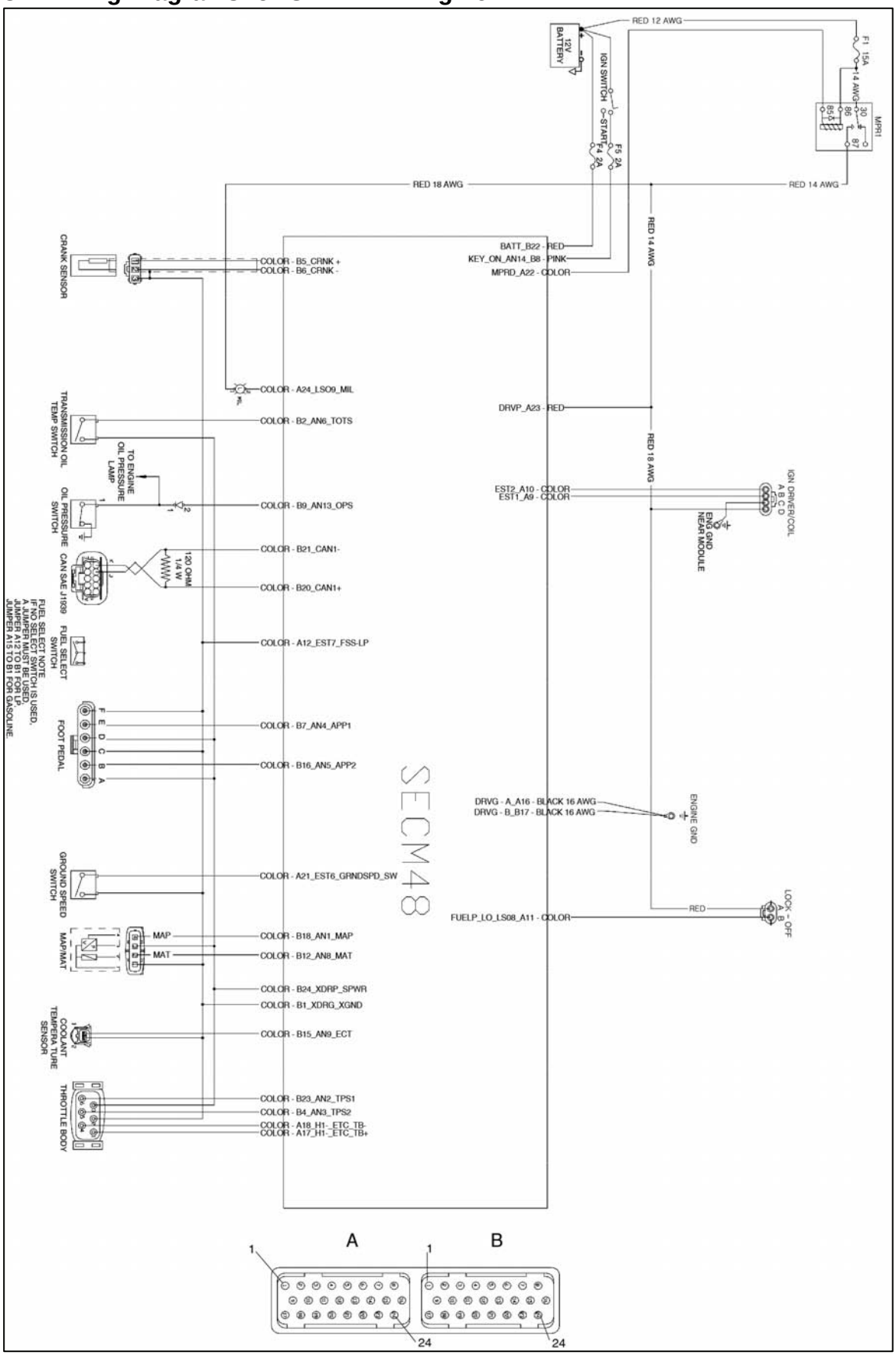
Ignition System

The Ignition system of G424F engine is the same as that of G424FE engine. See, “Ignition system of G424FE EMS overview”

SECM

The SECM of G424F engine is the same as that of G424FE engine. See, “SECM of G424FE EMS overview”

SECM Wiring Diagrams for G424F LP Engine



EMS Inspection and Repair

Engine Control Module (SECM)

The 48-pin Small Engine Control Module (SECM) and sensors provide the computational power, algorithm logic, sensor inputs and control outputs to control the system. The SECM receives signals from the sensors, digitizes these signals, and then, through algorithms and calibration MAPs, computes the desired output response to effect control of fuel, spark and air to the engine. The SECM also provides a variety of other functions and features. These include system monitoring and diagnostics to aid in maintaining efficient system operation and auxiliary control.



SECM/sensor inputs and control output specifications are specific to the application, but include a selection of the following:

Analog Inputs

The 48-pin SECM is equipped with sufficient analog inputs for the following sensors.

- Manifold Absolute Pressure (MAP) 1bar MAP, 0 to 5 V
- Manifold Air Temperature (MAT)
  -40°F to 266°F (-40ºC to 130ºC) range, 48 kohm to 85 ohm sensor range
- Throttle Position Sensor 1&2 (TPS1 & TPS2) 0 to 5 V
- Foot Pedal Position 1&2 (FPP1 & FPP2) 0 to 5 V
- Coolant Temperature Sensor (CTS)
  -40°F to 266°F (-40ºC to 130ºC) range,
  48K ohm to 85 ohm sensor range
- Fuel Temperature Sensor (FTS)
  -40°F to 266°F (-40ºC to 130ºC) range,
  48K ohm to 57 ohm sensor range
- HEGO (3) 0 to 1 V
- Auxiliary Analog Input (2) 0 to 5 V
- Battery Voltage (Vbatt) (1) 8-18 V

With the exception of battery voltage, all inputs are 0-5 Vdc, ground referenced. Resolution should be 0.1% or better. Accuracy should be 2% or better.

Frequency/Position Inputs

- Crankshaft position
  Variable reluctance (2-wire, 200 Vpp max) or 0-5 V Hall Effect with calibration selectable pull-up resistor for open collector sensors Permits speed resolution of 0.25 rpm and crankshaft position resolution of 0.5º
- Camshaft position
  Variable reluctance (2-wire, 200 Vpp max) or 0-5 V Hall Effect with calibration selectable pull-up resistor for open collector sensors.

Digital Inputs

- Oil pressure switch
  Normally open, internal pull-up resistor provided to detect external switch to ground
- Transmission oil temperature switch
  Normally open, internal pull-up resistor provided to detect external switch to ground
- Fuel select switch
  Three-position switch for bi-fuel applications to detect gasoline mode, LPG mode, and fuel off (center switch position)
- Ground speed select switch
  Permits selecting two different maximum engine speeds
- Vswitched
  Switched battery voltage

Outputs

- Saturated injector drivers (4)
  10A peak, 45 V max, 1 injector per channel capable of continuous on-time
  Driver circuit designed for minimum turn-on/turn-off delay
  Minimum pulse width resolution of 1 usec

- FTV drivers (2)
  10A peak, 45V max. To drive an on/off fuel trim valve with a minimum impedance of 5 ohms
  Capable of continuous on-time
  Drive circuit designed for minimum turn-on /turn-off delay
  FTVs will be pulse width modulated between 8 and 40 Hz with a minimum pulse width resolution of 50 usec

- Fuel lock-off solenoid valve
  Low side switch, 10A peak, 4A continuous 45 V max

- Gasoline fuel pump drive
  Low side switch, 10A, 4A continuous 45 V max

- Electronic Spark Timing (EST) (4)
  TTL compatible outputs Software configured for coil-on-plug ignition system

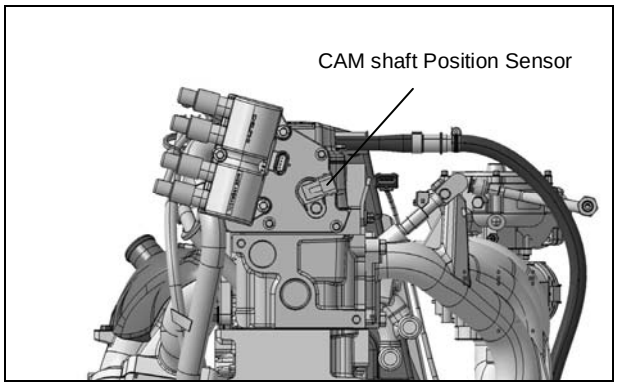
- Throttle control (1)
  H-Bridge, 5A peak, 2.5A continuous at 2500 Hz PWM includes current feedback for diagnostic purposes.

- MIL (malfunction indicator lamp)
  Low side switch, sufficient to drive a 7W incandescent lamp continuously

- CANBus
  CAN 2.0b serial communication for J1939 communications, programming and diagnostics.
  Requires proper termination resistance per CAN 2.0b.

Camshaft Position Sensor (G424FE- Dual Fuel Only)

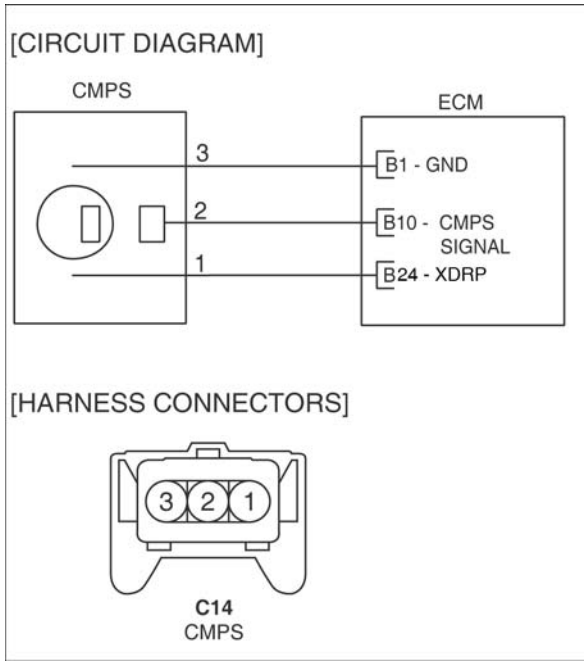
Component Location



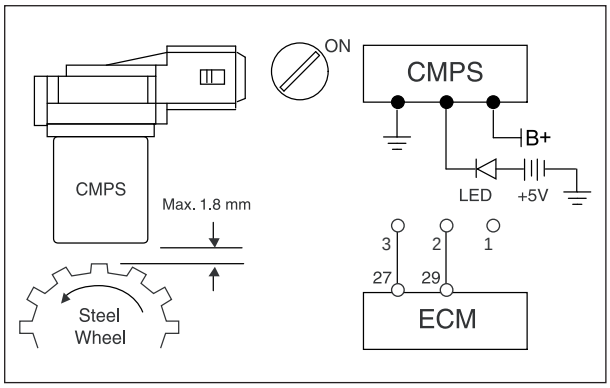
Description

The Camshaft Position Sensor (CMPS) is a sensor that detects the compression TDC of the NO.1 cylinder.
The CMPS consists of a hall type sensor and a target on the end of the in take camshaft.
When the target triggers the sensor, the sensor voltage is 5V. If not, the sensor voltage is 0V.
These CMPS signal is sent to the ECM and the ECM uses the CMPS signal for synchronizing the firing of sequential fuel injectors.

Schematic Diagram



Sensor Inspection



1. Turn ignition switch to OFF position and then disconnect CMPS connector.

2. Remove the CMPS from the engine.

3. Turn ignition switch to ON position.

4. Apply battery voltage to the terminal 1 and ground terminal 3 of CMPS as shown in the figure.

5. Install a LED between +5V power and CMPS terminal 2, and then set a steel wheel (or anything made of steel; hammer, wrench, bolt and nut etc.) at the CMPS's tip.

6. Rotate the steel wheel slowly and check if the LED flashes light.

• If the LED blinks, the CMPS works normally.

Removal

1. Disconnect the negative battery cable.

2. Disconnect the CMP sensor electrical connector.

3. Remove harness clamp from CMP sensor support plate.

4. Remove the screw and lock washer retaining the CMP sensor.

5. Remove the CMP sensor and O-ring.

6. Remove O-ring from CMP sensor and discard.

Installation

1. Install new O-ring on CMP sensor.

2. Lubricate O-ring with clean engine oil.

3. Install the CMP sensor into the CMP sensor support plate.

Note: Before installing retaining screw, verify the CMP sensor is fully seated.

4. Install retaining screw and lock washer. Tighten retaining screw.

Tighten

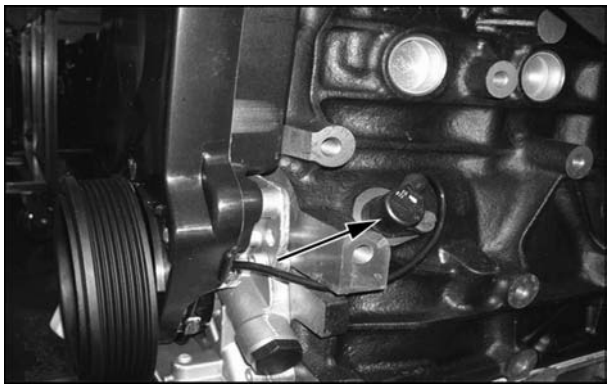
• Bolts: 6 N•m(53lbf in).

5. Connect the electrical connectors. Verify that the connectors click/lock into place.

6. Install harness clamp to CMP sensor support plate.

Crankshaft Position Sensor

Component Location



Crank Position Sensor



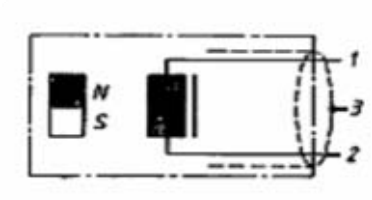
Connector

Specification

Terminal 1: Signal (+)

Terminal 2: Signal (-)

Terminal 3: Ground



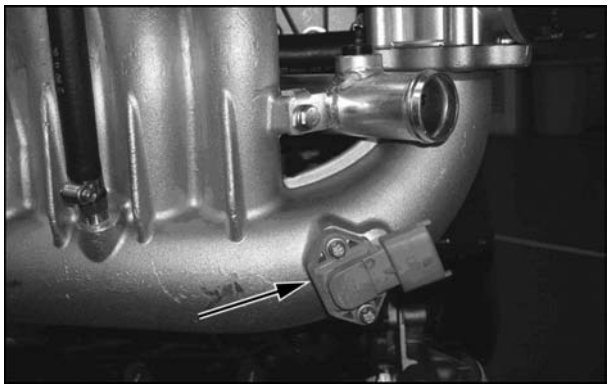
Removal

1. Remove the timing belt front cover. See Timing Belt Front Cover, Remove.
2. Disconnect the crankshaft/rpm sensor electrical harness.
3. Remove the capscrew retaining the crankshaft / rpm sensor.
4. Remove the crankshaft/rpm sensor.

Install

1. Install the crankshaft/rpm sensor into the engine block.
2. Install the capscrew to retain the crankshaft/rpm sensor. Tighten capscrew to 8 N◦m (71 lbf ft).
3. Connect the crankshaft/rpm sensor electrical harness.
4. Install the timing belt front cover. See Timing Belt Front Cover, Install

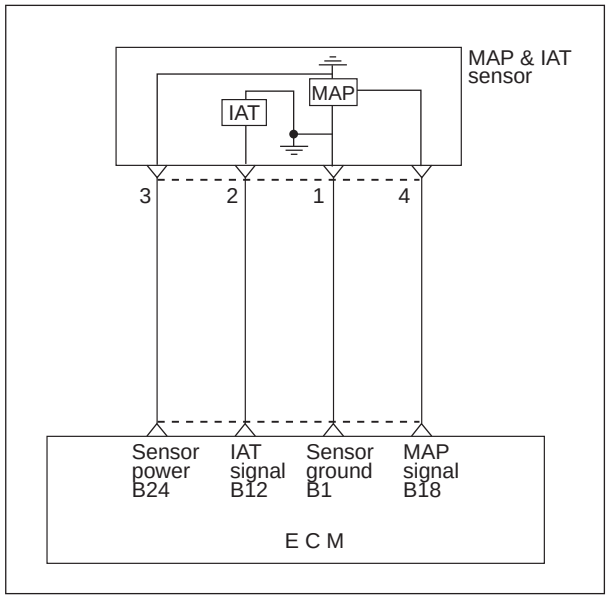
MAP (Manifold Absolute Pressure) Sensor



MAP sensor

The manifold absolute pressure (MAP) sensor is a pressure sensitive variable resistor. It measures changes in the intake manifold pressure which result from engine load and speed changes, and converts this to a voltage output. The MAP sensor is also used to measure barometric pressure at start up, and under certain conditions, allows the ECM to automatically adjust for different altitudes. The ECM supplies 5 volts to the MAP sensor and monitors the ECM supplies 5 volts to the MAP sensor and monitors the voltage on a signal line. The sensor provides a path to voltage on a signal line. The sensor provides a path to ground through its variable resistor. The MAP sensor in put affects fuel delivery and ignition timing controls in the ECM.

Ciruit Diagram



Sensor Inspection

1. Measure the voltage between terminals 1 and 4 of the MAP sensor connectors.
Terminal 4 : MAP sensor ground
Terminal 1 : MAP sensor output

Engine state	Test specification
Ignition SW. ON	4~5V
At idle	0.5~2.0V

2. If the voltage deviates from the standard value, replace the MAP sensor assembly.

Removal

1. Disconnect the negative battery cable.

2. Disconnect the electrical connector from the MAP/MAT sensor.

3. Remove the two screws retaining the MAP/MAT sensor to the intake manifold.

4. Remove MAP/MAT sensor.

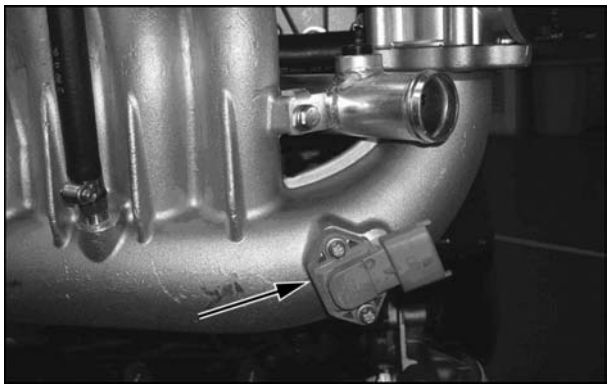
Installation

1. Place the MAP/MAT Sensor in position on the intake manifold and install the two retaining screws. Tighten retaining screws to 6 N◦m (53 lbf ft)

2. Connect the electrical connector to the MAP/MAT sensor. Verify that the connector clicks/locks into place.

3. Connect the negative battery cable.

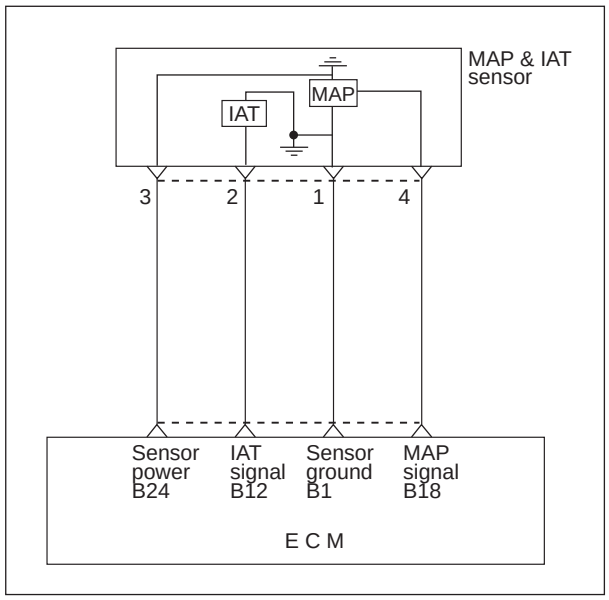
IAT (Intake Air Temperature) Sensor



MAP sensor

The intake air temperature sensor (IAT Sensor), built in to the MAT sensor, is a resistor-based sensor detect the intake air temperature. According to the intake air temperature information frim the sensor, the ECM will control the necessary amount of fuel injection.

Ciruit Diagram



Sensor Inspection

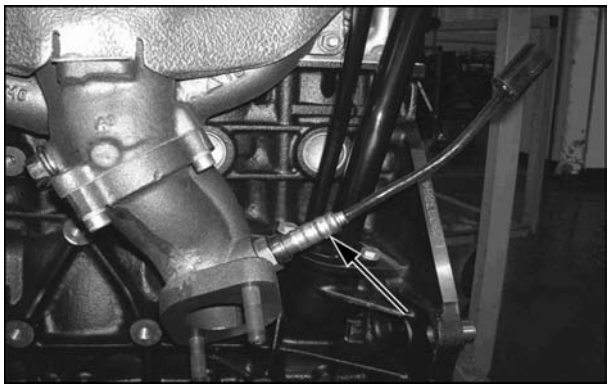
1. Using a multimeter, measure the IAT sensor resistance between terminals 3 and 4.

IG.SW.ON	Temperature ℃ (°F)	Resistance(kΩ)
	0 (32)	4.5 ~ 7.5
	20 (68)	2.0 ~ 3.0
	40 (104)	0.7 ~ 1.6
	80 (176)	0.2 ~ 0.4

2. If the resistance deviates from the standard value, replace the intake air temperature sensor assembly.

Oxygen Sensor (Pre-Catalyst)

Component Location



Pre - Catalyst Oxygen Sensor

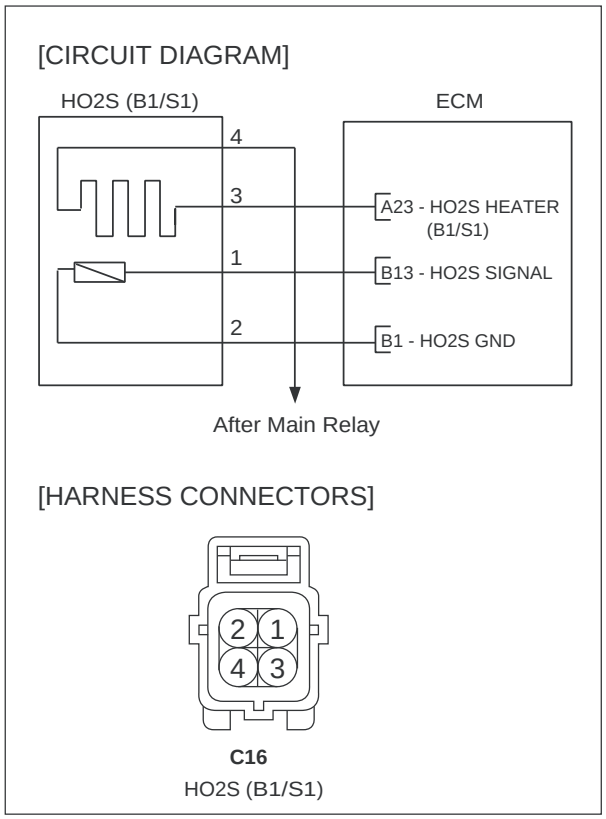
Description

The heated oxygen sensor is mounted on the front side of Catalytic Muffler, which detects the oxygen concentration in the exhaust gas. The heated oxygen sensor produces a voltage that varies between 0V and 1V. When the air/fuel ratio is lean, the oxygen concentration in the exhaust gas increases and the front HO2S outputs a low voltage (approximately0~0.1V). When the air/fuel ratio is rich, the oxygen concentration in the exhaust gas decreases and the front HO2S outputs a high voltage (approximately0.8~1V). The ECM constantly monitors the HO2S and increases or decreases the fuel injection duration by using the HO2S signal, which is called closed-loop fuel control operation.

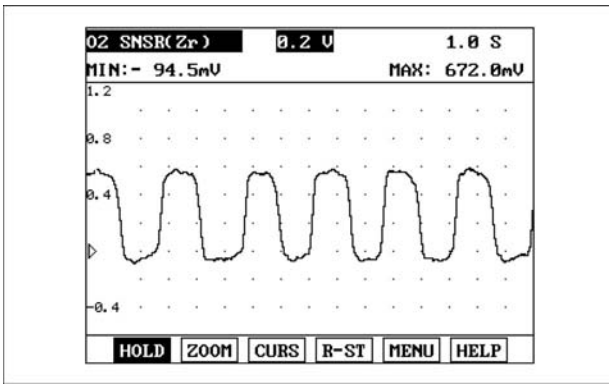
Specification

Temperature		Front HO2S Heater Resis-tance(Ω)	Temperature		Front HO2S Heater Resistance (Ω)
(℃)	(°F)		(℃)	(°F)	
20	68	9.2	400	752	17.7
100	212	10.7	500	932	19.2
200	392	13.1	600	1,112	20.7
300	572	14.6	700	1,292	22.5

Schematic Diagram



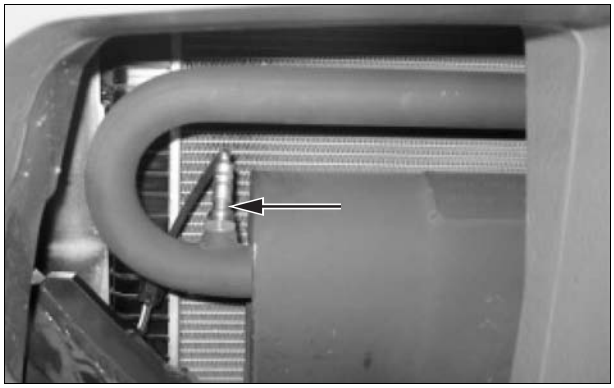
Signal Wave Form



If you release the accelerator pedal suddenly after engine running about 2600 rpm, fuel supply will stop for short period and the O2 sensor service data will display values 200mV or lower. When you suddenly press on the accelerator pedal down, the voltage will reach 0.6 ~ 1.0 V. When you let the engine idle again, the voltage will fluctuate between 200 mV or lower and 0.6 ~ 1.0 V. In this case, the O2sensor can be determined as good.

Oxygen Sensor (Post-Catalyst)

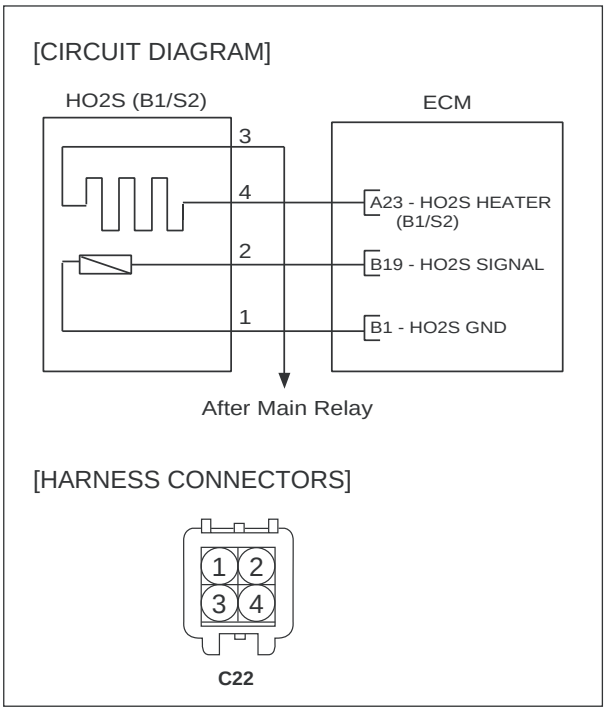
Component Location



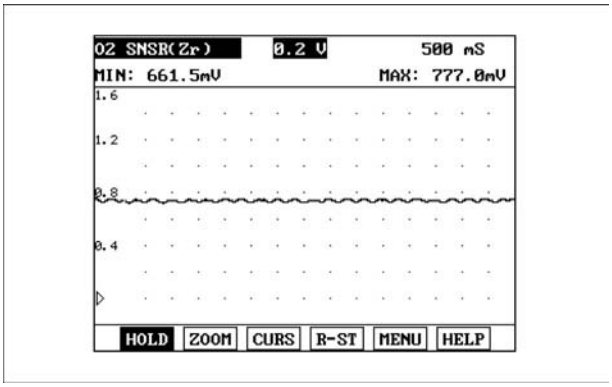
Description

The rear heated oxygen sensor is mounted on the rear side of the Catalytic Muffler, which detects the catalyst efficiency. The rear heated oxygen sensor (HO2S) produces a voltage between 0V and 1V. This rear heated oxygen sensor is used to estimate the oxygen storage capability. If a catalyst has good conversion properties, the oxygen fluctuations are smoothed by the oxygen storage capacity of the catalyst. If the conversion provided by the catalyst is low due to aging, poisoning or misfiring, then the oxygen fluctuations are similar to signals from the front oxygen sensor.

Schematic Diagram



Signal Wave Form



The amplitude of the signal output of the rear HO2S is small compared to the front HO2S because the rear HO2S detects emission gas purified by the catalytic converter. This illustration is the normal signal waveform of the rear HO2S at idle.

Specification

Temperature		Rear HO2S Heater Resis-tance(Ω)	Temperature		Rear HO2S Heater Resistance(Ω)
(℃)	(℉)		(℃)	(℉)	
20	68	9.2	400	752	17.7
10	212	10.7	500	932	19.2
200	392	13.1	600	1,112	20.7
300	572	14..6	700	1,272	22.5

ECT (Engine Coolant Temperature) Sensor

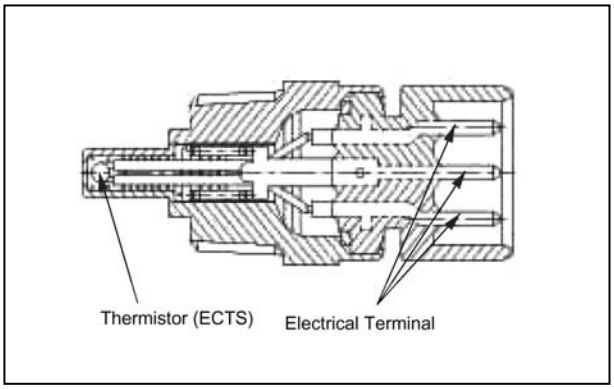
Component Location



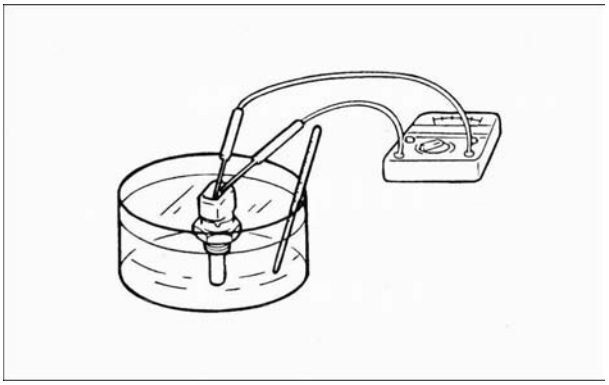
ECT Senser

Description

The Engine Coolant Temperature Sensor (ECTS) is located in the engine coolant passage of the cylinder head for detecting the engine coolant temperature. The ECTS uses a thermister whose resistance changes with the temperature. The electrical resistance of the ECTS decreases as the temperature increases, and increases as the temperature decreases. The reference 5 V in the ECM is supplied to the ECTS via a resistor in the ECM. That is, the resistor in the ECM and the thermistor in the ECTS are connected in series. When the resistance value of the thermistor in the ECTS changes according to the engine coolant temperature, the output voltage also changes. During cold engine operation the ECM increases the fuel injection duration and controls the ignition timing using the information of engine coolant temperature to avoid engine stalling and improve drivability.



Sensor Inspection



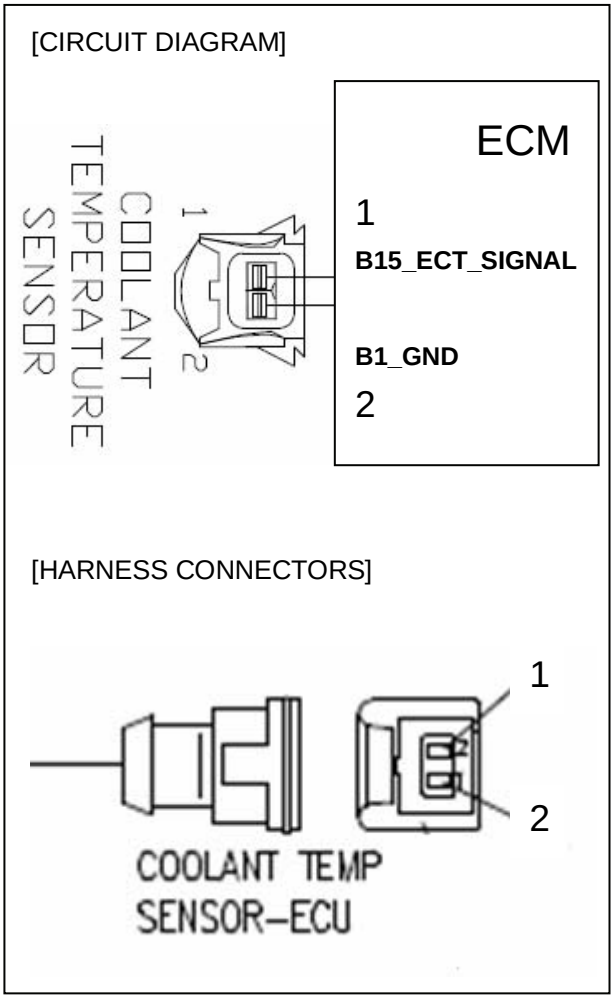
1. Remove the engine coolant temperature sensor from the intake intake manifold.

2. With the temperature sensing portion of the engine coolant temperature sensor immersed in hot water, check resistance.

Temperature ℃ (°F)	ECTS Resistance(kΩ)
-20(-4)	14.13~16.83
0(32)	5.79
20(68)	2.31~2.59
40(104)	1.15
60(140)	0.59
80(176)	0.32

3. If the resistance deviates from the standard value greatly, replace the sensor.

Schematic Diagram



Installation

1. Install engine coolant temperature sensor and tighten it to specified torque.

Tightning torque

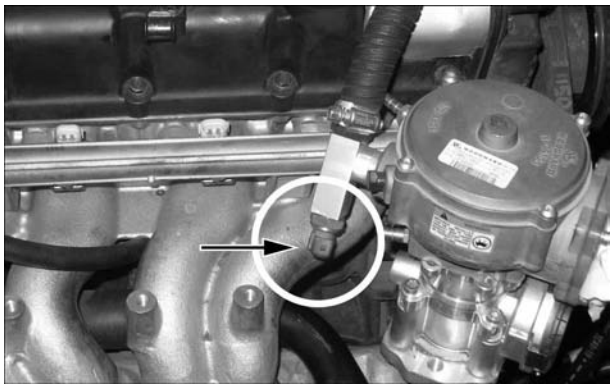
Engine coolant temperature sensor "
15~20Nm (150~200 kg.cm, 11~15 lb.ft)

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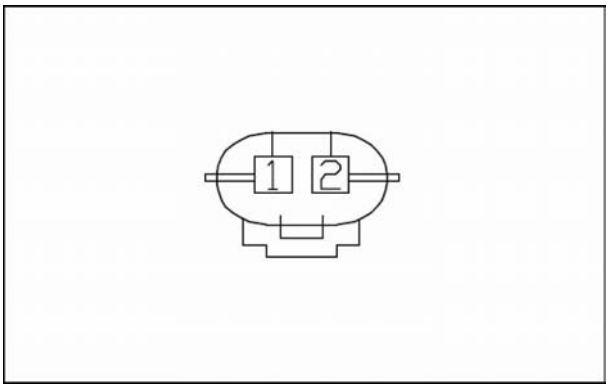
2. Connect the harness connector securely.

LP Fuel Temperature Sensor

Location



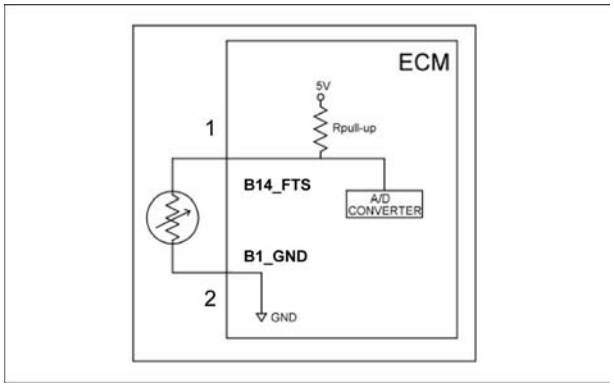
[Harness Connectors]



Description

The LP Fuel Temperature Sensor (FTS) is located in the LP fuel passage of the LP mixer for detecting the LP fuel temperature. The FTS uses a thermistor whose resistance changes with the temperature. The electrical resistance of the FTS decrease as the temperature increase, and increase as the temperature decrease. The reference 5V in the ECM is supplied to the FTS by way of a resister in the ECM. That is, the resistor in the ECM and the thermistor in the FTS are connected in series. When the resistance value of the thermistor in the FTS changes according to the LP fuel temperature, the output voltage also change.

[Circuit Diagram]



Inspection

1. Remove the LP fuel temperature sensor from the adapter connected to LP mixer.

2. With the temperature sensing portion of the LP engine fuel temperature immersed in hot water, check resistance.

Temperature °C (°F)	FTS Resistance (Ohms)
-20(-4)	15462
0(32)	5896
20(68)	2498
40(104)	1175
60(140)	596
80(176)	323

3. If the resistance deviates from the standard value greatly, replace the sensor.

Angle Sensor-Accelerator

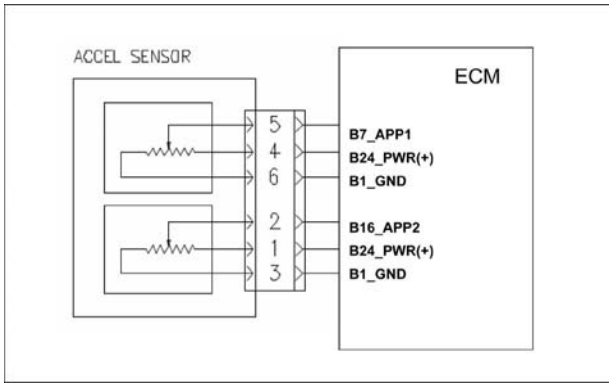
Location



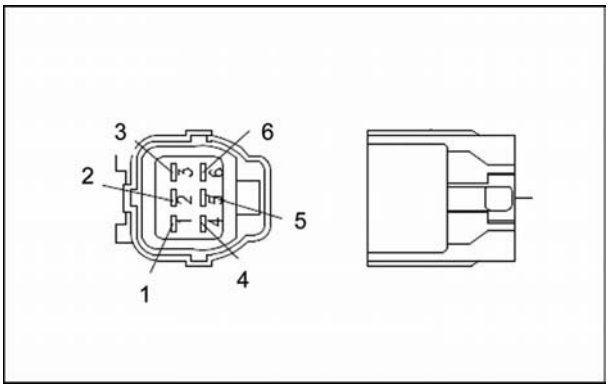
Description

Angle Sensor-Accelerator is located in the accelerator pedal assembly. The engine speed management deals with a Drive-by-wire system. Drive-by-wire refers to the fact that the MI-07 control system has no throttle cable from the foot pedal to the throttle body. Instead, the ECM is electronically connected both to the foot pedal assembly and the throttle body. The SECM monitors the foot pedal position and controls the throttle plate by driving a DC motor connected to the throttle. The DC motor actuates the throttle plate to correspond to the foot pedal position when the operator depresses the pedal. The SECM will override the pedal command above a maximum engine speed and below a minimum idle speed. The foot pedal assembly uses two potentiometers to detect pedal position. These two signals, accelerator pedal position 1 (APP1) and accelerator pedal position 2 (APP2) are sent directly to the SECM. The SECM uses a series of algorithms to self calibrate and cross check the signals from the pedal assembly.

[Circuit Diagram]



[Harness Connectors]



Inspection

1. Disconnect the Accelerator Pedal's connector from the main engine harness.

2. Inspect the electrical conditions with a follow basic specification.

Signal output is on condition that input voltage is ..... 5V±0.5%
Rated current :..... 20 mA
Power :..... 100 mW
Wire width :..... 20AWG
- At start point : Signal 'A'..... 0.4V±0.1V
Signal 'B'..... 4.5V±0.1V
- At end point(Push for end) :
Signal 'A'..... 3.60V±0.15V
Signal 'B'..... 1.39V±0.15V

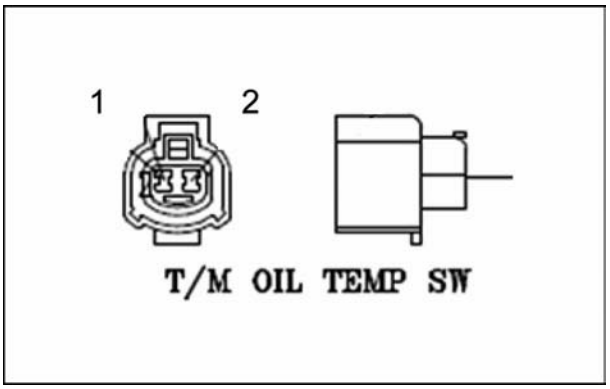
3. If the result value is out of the specification, replace the Accelerator Pedal.

Transmission Oil Temperature Switch

Location



[Harness Connectors]



Description

Transmission Oil Temperature Switch is located in the adapter on transmission (T/M) for operating by the transmission (T/M) oil temperature change. This switch is normally open, and then it is closed as the T/M oil temperature Increases to the 125±3°C. Actually if the switch is closed by high T/M oil temperature, the ECM makes engine shutdown with fault set. If the T/M oil temperature decreases to the 118°C, the switch is open again and the engine also can run. This function can protect the engine of Tier-3 and Non cert folk lift trucks from damage as overheating.

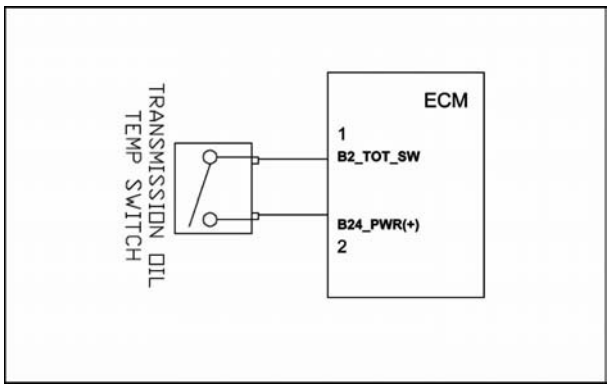
Inspection

1. Remove the Transmission Oil Temperature Switch from the transmission.

2. Use an ohmmeter to check the continuity between the 1 terminal and the 2 terminal. If there is continuity, replace the Transmission Oil Temperature Switch.

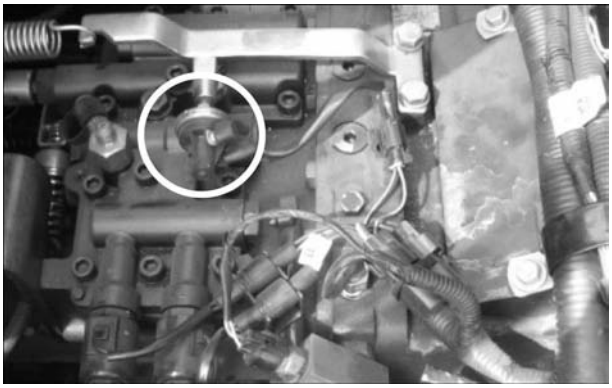
3. The Transmission Oil Temperature Switch is the 'ON/OFF' switch. So during the normal status the switch circuit should be open.

[Circuit Diagram]

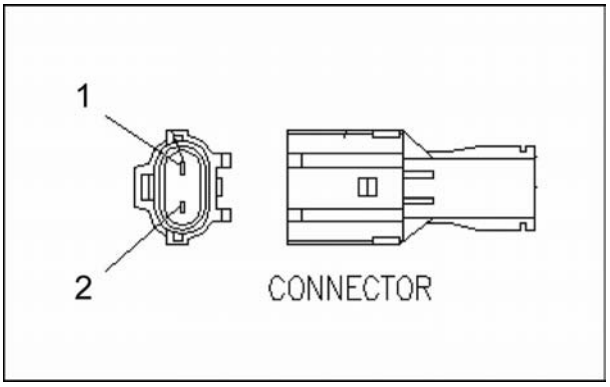


Ground Speed Limit Switch (optional)

Location



[Harness Connectors]



Description

Ground Speed Limit Switch is located in the pressure port on transmission (T/M) for operating by the transmission (T/M) oil pressure change. This switch is normally opened, and then it is closed as the T/M oil pressure increases. Actually the switch is closed by increasing of the T/M oil pressure after engine cranking. And if the inching pedal is pushed by a driver the switch is opened again by decreasing of the T/M oil pressure. ECM can control the travel speed of the folk lift trucks with this switch. Also the maximum travel speed of Tier-3 and Non cert fork lift trucks is an optional feature that can be easily activated using the MotoView Service Tool. This feature may be of particular interest to customers with indoor warehouse operations.

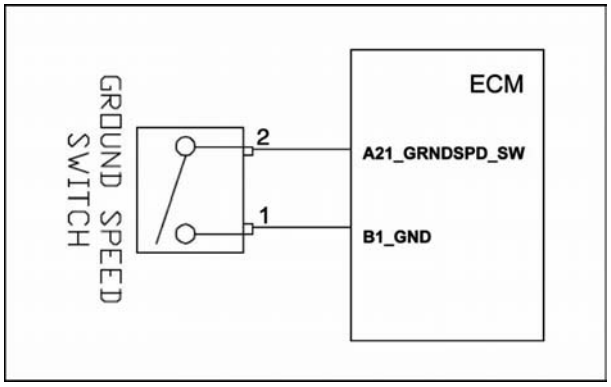
Inspection

1. Remove the Ground Speed Limit Switch from the transmission.

2. Use an ohmmeter to check the continuity between the 1 terminal and the 2 terminal. If there is continuity, replace the Ground Speed Switch.

3. The Ground Speed Limit Switch is the 'ON/OFF' switch. So during the normal status the switch circuit should be open.

[Circuit Diagram]

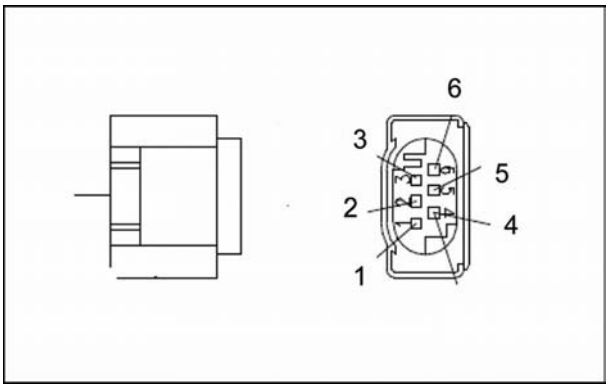


Electronic Throttle Body

Location



[Harness Connectors]



Description

The MI-07 system uses electronic throttle control (ETC). The SECM controls the throttle valve based on engine RPM, engine load, and information received from the foot pedal. Two potentiometers on the foot pedal assembly monitor accelerator pedal travel. The electronic throttle used in the MI-07 system is a Bosch 32mm electronic throttle body DV-E5. The DV-E5 is a single unit assembly, which includes the throttle valve, throttle-valve actuator (DC motor) and two throttle position sensors (TPS). The SECM calculates the correct throttle valve opening that corresponds to the driver's demand, makes any adjustments needed for adaptation to the engine's current operating conditions and then generates a corresponding electrical (driver) signal to the throttle-valve actuator.

Inspection

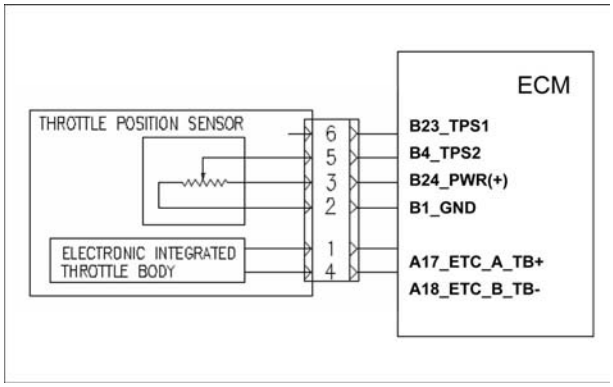
1. Check for loose, dirty or damaged connectors and wires on the harness

2. Check the throttle assembly motor housing for coking, cracks, and missing cover-retaining clips

3. Check the resistance of TPS sensor. (refer as blow chart)

SENSOR	POINT TO POINT	EXPECTED RANGE
TPS (Throttle Position Sensor)	TPS PIN 2(GND) TO PIN 6(TPS1 SIGNAL)	1.25KΩ +/- 30%
	TPS PIN 3(PWR) TO PIN 6(TPS1 SIGNAL)	1.25KΩ +/- 30%
	TPS PIN 1(+DRIVER) TO PIN 4(-DRIVER)	~3.0KΩ +/- 30%

[Circuit Diagram]



Chapter 6. LPG FUEL DELIVERY SYSTEM

G424FE LP System Inspection and Repair

Removal and Installation

⚠ WARNING - PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**

- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**

- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

⚠ CAUTION

The regulator/converter and mixer are part of a certified system complying with EPA and CARB 2007 requirements. Only trained, certified technicians should perform disassembly, service or replacement of the regulator/ converter or mixer.

Hose Connections

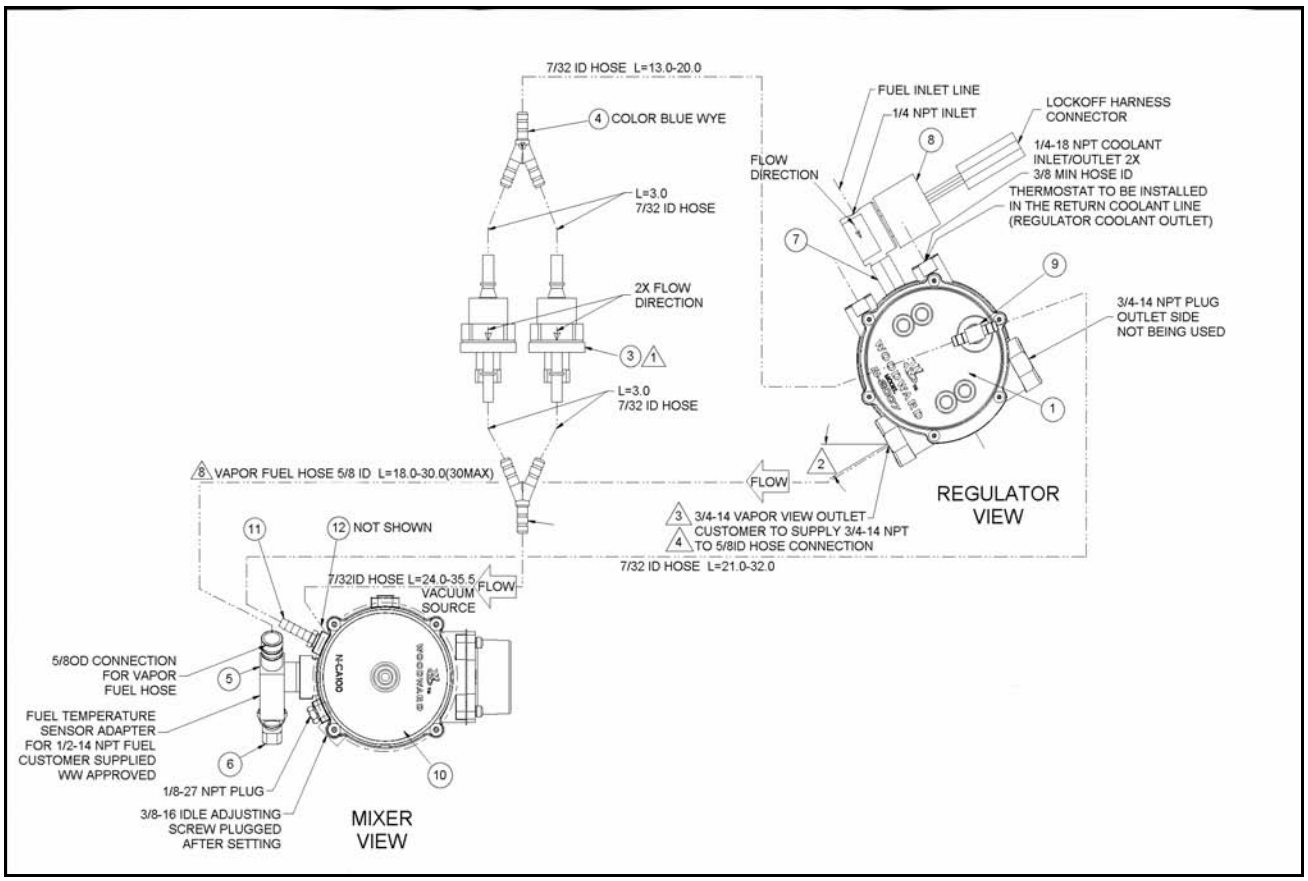
Proper operation of the closed loop control greatly depends on the correct vacuum hose routing and fuel line lengths. Refer to the connection diagrams below for proper routing and maximum hose lengths when reinstalling system components.

NOTE: Preferred mounting of regulator is off engine.

Hose Specifications

Vacuum hose to comply to SAE 1403 Type I or SAE J30 R7 R8 / EPDM textile reinforced / -40° F to +257° F (-40° C +125° C / Inside Diameter: 7/32" (5.56mm)

Certified System Connections



DWG NO 5555-1201

Figure 26. Hose Connections for Certified Systems

DIAGRAM NOTES

1. Trim valves must be positioned vertically with flow arrows in position shown
2. Fuel outlet must be min 15° below horizontal position
3. Only one 90° fitting permissible on vapor fuel line between mixer and regulator (As shown the temp sensor adaptor is considered the one 90° fitting.)
4. Vapor fuel fittings (regulator and mixer) must have minimum ID of 0.46" (11.68mm)
8. Vapor hose length to be as short as possible and have no restrictions for best regulator performance

1. N-2007 Regulator
2. Plastic WYE Fitting (black color) for 7/32" (5.56mm) ID Tube Hose
3. Valve (TEV Bosch Canister)
4. Plastic WYE Fitting (blue color) for 7/32" (5.56mm) ID Tube Hose
5. Adapter (temperature sensor)
6. Sensor (coolant, temperature)
7. Nipple (.625 hex 4mp, 2.5L steel)
8. Solenoid (AFS Lock Off Valve)
9. Brass Tee Fitting. 1/4 Tube x 1/8 NPTF x 1/4 Tube
10. CA100 Mixer
11. 1/4" (6.35mm) hose barb to 1/8" (3.2mm) male pipe, 125HBL, .062 flow ID
12. 1/4-28 UNF x 1/4" (6.35mm) hose barb

Removal and Installation of N-2007 LP Regulator

Follow the procedures below for removal and reinstallation of the N-2007 regulator in certified systems.

N-2007 Removal Steps

Refer to **Figure 28.**

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.

2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.

3. Key switch in "OFF" position.

4. Remove the fuel inlet line (1) from the lock-off, the two vacuum lines (2) from the branch-tee fitting in the regulator vent and disconnect the lock-off connector (3).

5. Remove the four rear-mounting bolts that hold the regulator to the support bracket. This will allow easier access to the remaining hose clamps.

6. Remove the two cooling lines (4) from the regulator. NOTE: Either drain the coolant system or clamp off the coolant lines as close to the regulator as possible to avoid a coolant spill when these lines are disconnected.

7. Remove the fuel vapor outlet hose (5) from the regulator.

8. Remove the nipple extension (6) with the lock-off from the regulator.

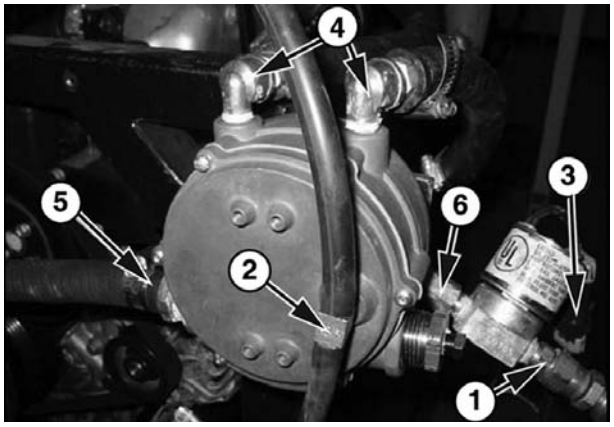


Figure 28. N-2007 Regulator in Certified System

N-2007 Installation Steps

Refer to **Figure 28.**

1. Install the nipple extension (6) with the lock-off to the regulator.

2. Install the fuel vapor outlet hose (5) to the regulator.

3. Install the two cooling lines (4) to the regulator.

4. Install the four rear-mounting bolts that hold the regulator to the support bracket. Use a torque wrench and tighten each bolt to 60-70 lbf-in (6.78-7.91 N-m).

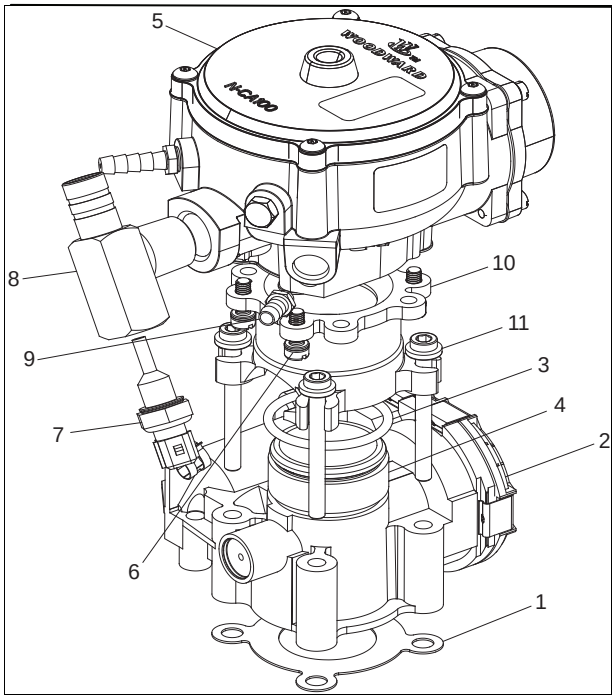
5. Install the fuel inlet line (1) to the lock-off, the two vacuum lines (2) to the branch-tee fitting in the regulator vent and re-connect the lock-off connector (3).

6. Open the liquid outlet valve in the forklift cylinder or fuel storage container.

Removal and Installation of CA100 Mixer for G424FE

Follow the procedures below for removal and reinstallation of the CA100 mixer in certified systems.

CA100 Certified Mixer Removal Steps



1. Gasket-ITB
2. ITB
3. O-Ring
4. O-Ring Spacer
5. Mixer
6. Bolt
7. Fuel Temp Sensor
8. Adapter-Fuel Temp Sensor
9. Fitting-Vacuum Small
10. Apollo Adapter-ITB, Mixer
11. Bolt

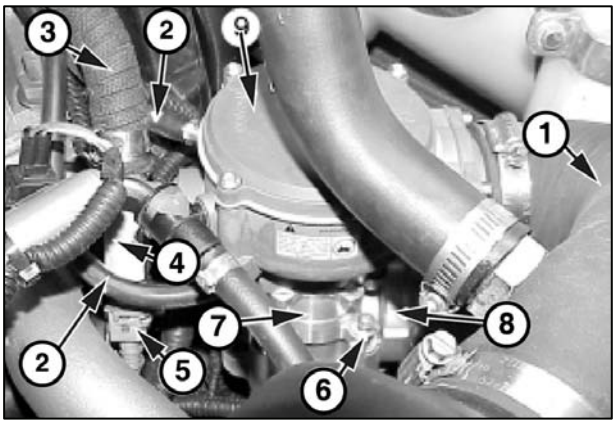


Figure 30. CA100 Mixer in Certified System

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.

2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.

3. Key switch in “OFF” position.

4. Remove the air cleaner hose (1).

5. Mark the two vacuum lines (2) to the mixer for identification, as they must be reinstalled correctly for proper operation. Remove the two vacuum lines (2).

6. Remove vapor fuel inlet line (3) from the fuel temperature sensor fitting (4).

7. Disconnect the fuel temperature sensor connector (5).

8. Disconnect the wires leading to the electronic throttle body by pinching the lock tabs on either side of the wiring harness connector. (See Figure 31 for location of connector)

9. Loosen the four bolts (6) that secure the mixer/adapter/throttle body assembly to the intake manifold.

10. Remove the mixer (9), the adapter (7), and the throttle body (8) as an assembly by gently pulling upwards. Take care not to drop anything down the intake manifold.

11. Gently wiggle and pull to separate mixer and adapter from the throttle body. Take note of the adapter orientation on the mixer, as it must be reinstalled correctly for proper fit on the throttle.

12. Remove the four mounting screws that attach the throttle body adapter to the mixer.

13. Remove the fuel temperature sensor (not shown) from the tee (4).

14. Remove the fuel temperature sensor fitting from the mixer. Take note of the fitting’s orientation on the mixer, as it must be reinstalled correctly for proper fit.

15. Remove the short vacuum port barb from the mixer. (See **Figure 32** for location of port barb on mixer.)

NOTE : A plastic O-ring spacer and an O-ring are inside the mixer/adapter assembly. Be careful not to lose these items when removing the assembly from the throttle (Figure 31).

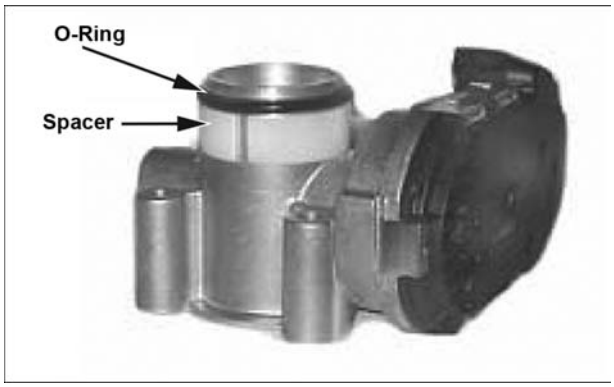


Figure 31. O-Ring and Spacer Within Mixer Adapter Assembly

CA100 Certified Mixer Installation Steps

Refer to **Figure 30.**

1. Install the vacuum port barb onto the mixer (9).

2. Install the fuel temperature sensor fitting (4) onto the mixer.

3. Install the fuel temperature sensor into the fitting.

4. Ins tall the four mounting screws that attach the throttle adapter (7) to the mixer. See Figure 32. Torque bolts to 30-40 lbf-in (3.39-4.52 N-m).

5. Position the mixer/adapter assembly onto the throttle body (8), then drop in the four mounting bolts (6) and gently push down on the assembly until it rests on the throttle body. Be careful not to pinch the O-ring. (See Figure 31.)

6. Attach the mixer/throttle body assembly to the intake manifold, making sure gasket is in place. Tighten the four mounting bolts.

7. Connect the wiring harness to the throttle body. (See Figure 31 for location of connector.) Connect the fuel temperature sensor connector (5) to the sensor.

8. Install the vapor fuel inlet line (3) to the fuel temperature sensor fitting.

9. Install the two vacuum lines (2) to the mixer using the previous marks for identification. Vacuum lines must be installed correctly for proper operation.

10. Install the air cleaner hose (1).

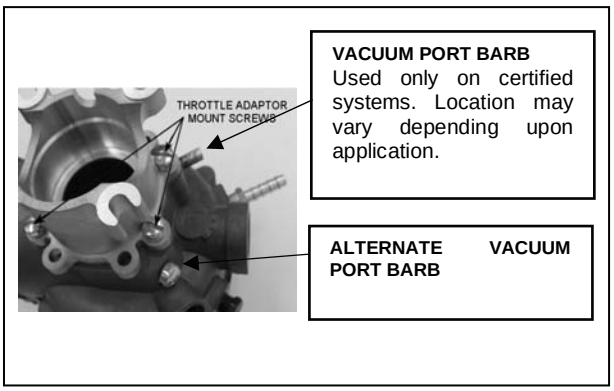

THROTTLE ADAPTOR MOUNT SCREWS
VACUUM PORT BARB
Used only on certified systems. Location may vary depending upon application.
ALTERNATE VACUUM PORT BARB

Figure 32. Throttle Adapter Mount Screws

Tests and Adjustments

⚠ WARNING—PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**
- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**
- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

⚠ CAUTION

The regulator/converter and mixer are part of a certified system complying with EPA and CARB 2007 requirements. Only trained, certified technicians should perform disassembly, service or replacement of the regulator converter or mixer.

N-2007 Regulator Service Testing

For checking the N-2007 regulator/converter operation, the following tests can be performed (See Chapter 5 for removal/installation of the N-2007 regulator). To check the secondary regulation (output) a simple vacuum hand pump can be used to simulate the vacuum signal transmitted from the air/fuel mixer when the engine is running. See listing below for required hardware.

Break-Off Test

Secondary Stage Test Hardware

1. Hand vacuum pump

2. Regulator vapor outlet test fitting 3/4” NPT x 1/4” hose barb

3. Union Tee 1/4” NPT with three 1/4” NPT x 1/4” hose barb

4. Vacuum hose

5. 0-3” WC Magnehelic gauge (inches of water column)

Secondary Stage (Break-Off) Test

1. Connect the vacuum pump, the Magnehelic gauge and the regulator vapor outlet to the Union Tee fitting (Figure 34). Make sure there is no leakage at any of the fittings.

2. Using the vacuum pump slowly apply enough vacuum to measure above -2” WC on the gauge. This vacuum signal opens the secondary valve in the N-2007 regulator/converter.

3. Release the vacuum pump lever and you will see the gauge needle start falling back toward zero. When the pressure drops just below the specified break-off pressure (-0.5 +/- 0.35 “ WC) of the secondary spring, the needle should stop moving.

4. At this point the secondary valve should close. If the secondary valve seat or the secondary diaphragm is leaking the gauge needle will continue to fall toward zero (proportional to the leak size). An excessively rich air/fuel mixture can be caused by a secondary valve seat leak and the regulator should be replaced.

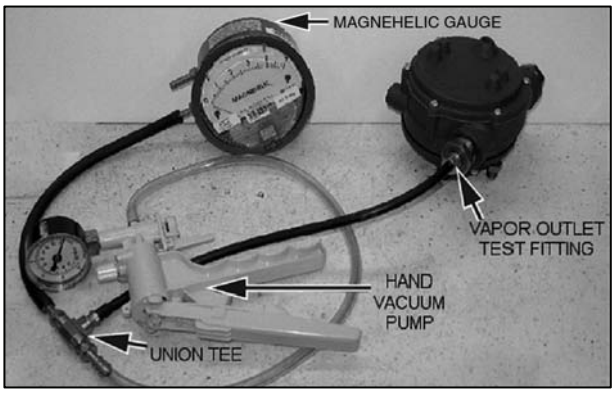


Figure 34. Secondary Stage Test Connection

Pressure Test

Primary Stage Test Hardware

1. Shop air pressure regulator adjusted to 100 psi

2. Shop air hose fitting (1/4" NPT to air hose)

3. Air hose

4. Test gauge fitting (1/16" NPT x 1/4" hose barb)

5. Vacuum hose or vinyl tubing

6. 0-60" WC Magnehelic gauge (inches of water column)

Primary Stage Pressure Test

1. Remove the primary test port plug from the side of the regulator and install the 1/16" NPT hose barb fitting (Figure 35).

2. Connect a compressed air line (shop air ~100psi) to the liquid propane fuel inlet of the N-2007 regulator (Figure 35).

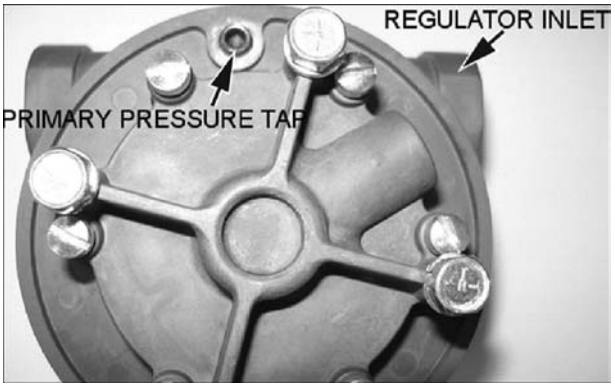


Figure 35. Primary Stage Test Connection

3. Apply compressed air, wait for air to exit the hose barb in the test port, and then connect the Magnehelic gauge (Figure 36) to the hose barb using the vacuum hose or vinyl tubing. This prevents the gauge from reading maximum pressure due to the large velocity of compressed air entering the primary chamber.

4. Make sure there is no leakage at any of the fittings. The static pressure should read between 40-60" of water column on the Magnehelic gauge and maintain a constant pressure for 60 seconds.

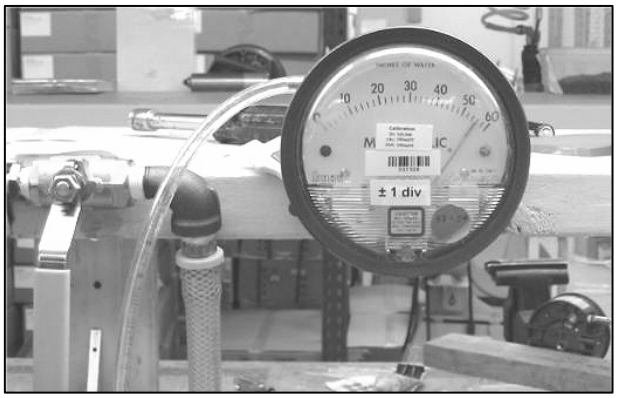


Figure 36. Magnehelic Gauge Connection to Hose Barb

5. If the pressure reading begins to increase, a leak is most likely present at the primary valve, either the primary valve o-ring or the valve itself. If a leak is present the regulator should be replaced.

6. If the pressure begins to decrease, the secondary seat is probably not making an adequate seal and is leaking. The regulator should be replaced.

7. If the test is successful, re-install the primary test port plug and check the fittings for leaks. See Chapter 5 for installation of the N-2007 regulator.

NOTE : The N-2007 primary stage pressure can also be tested at idle on a running engine. The N-2007 primary pressure should be between 40 inH20 (99.6mbar) and 55 inH20 (137 mbar) at 750 rpm, idle.

⚠ CAUTION

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**

- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**

Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.

AVV (Air Valve Vacuum) Testing

Purpose of Test

Check for excessive or inadequate pressure drop across CA100 mixer.

AVV Test Hardware

1. Union Tee fitting, 1/4" (6.35mm) NPT with three 1/4" (6.35mm) NPT x 1/4" (6.35mm) hose barbs

2. Vacuum hose

3. 0-20" H2O differential pressure Magnehelic gauge

AVV Test

1. Install Union Tee fitting in the hose between the FTVs and the AVV fitting. Connect this fitting to the low pressure port of the Magnehelic gauge (Figure 37).

2. Leave high pressure port of the Magnehelic gauge exposed to ambient pressure (Figure 37).

3. With the engine fully warmed up and running at idle (750 rpm) place the transmission in Neutral. The AVV should be between 5" and 8" H2O of pressure vacuum.

4. If the measured pressure drop is excessively high, check for sticking or binding of the diaphragm air valve assembly inside the mixer. Replace mixer if necessary.

5. If the measured pressure drop is low, check for vacuum leaks in the manifold, throttle, mixer, TMAP sensor and attached hoses.

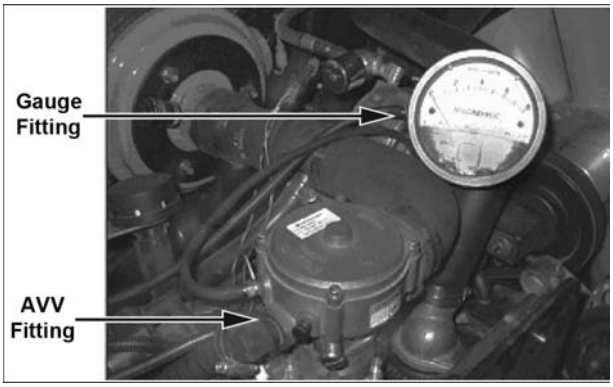


Figure 37. Magnehelic Gauge Connection

Ignition Timing Adjustment

With the MI-07 system, ignition-timing advance is controlled by the SECM.

Connection of the MI-07 Service Tool

To use the Service Tool, a USB (Universal Serial Bus) to CAN (Controller Area Network) communication adapter by KVaser will be required along with a Crypt Token (Figure 38). The Crypt Token acts as a security key allowing the laptop to retrieve the necessary data from the SECM.

1. Install the Crypt Token in an available USB port in the computer (Figure 39).

2. With the ignition key in the OFF position, connect the KVaser communication cable from a second USB port on the computer to the CAN communications cable on the engine. (*If your laptop computer does not have a second USB port an appropriate USB hub will need to be used).

3. Connect a timing light to the engine.

4. Turn the ignition key to the ON position (Do Not Start the Engine).

5. Launch the MotoView program on your computer and open the Service Tool display (Figure 40).



Figure 38. KVaser
Communication Adapter

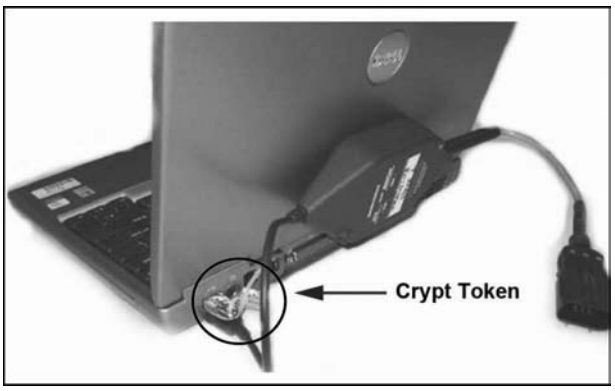


Figure 39. Crypt Token Installed on Laptop



Figure 40. Opening the Service Tool Display

Idle Mixture Adjustment

The CA100 mixer requires adjustment of the idle mixture screw to assure optimal emissions and performance. This adjustment accounts for minor part-to-part variations in the fuel system and assures stable performance of the engine at idle. Once adjusted, the idle mixture screw is sealed with a tamper proof cap, after which it need not be adjusted for the life of the vehicle.

Therefore, the only situations in which the idle mixture screw needs to be adjusted are when the engine is initially fitted with a fuel system at the factory and following the field replacement of the mixer. Under these situations, follow the procedures below for adjustment of the idle mixture screw.

Factory Test Preparation:

1. Install the MI-07 fuel system, wiring harness and SECM-48 control module on the engine.

2. All coolant hoses should be attached, filled with coolant and bled to remove any air.

3. Attach LPG fuel lines.

4. Attach wiring harness to battery power.

5. Attach exhaust system.

6. If present, set fuel select switch to LPG fuel.

When operated at the factory, it is critical to simulate the airflow found on a forklift at idle as nearly as possible in order to achieve the proper air valve lift in the mixer. It may be necessary to place a load on the engine to achieve the required airflow without overspeeding the engine. Means of achieving this load include:

a) Place an electrical load on the alternator. The alternator should be able to briefly hold loads of approximately 1.2 kW.

b) Attach the engine to a dynamometer.

Attach the Mototune Service Tool to the wiring harness and add parameter MAFPort to the display screen.

Factory Adjustment Procedure:

NOTE : Be sure engine is fully warm (ECT>167°F [75°C]) before performing the idle mixture adjustment.

1. Operating the engine on LPG fuel, start the engine and permit it to warm up until the coolant temperature (ECT on Mototune display) is approximately 167°F (75 oC).
2. Adjust the load until MAFPort equals 3.3 to 3.5 g/sec.
3. Mototune display parameter LP Fuel Control must display “Closed Loop”.
4. Use the Mototune Service Tool to monitor Duty Cycle % on the Mototune display.
5. To adjust the idle mixture screw, use a hex or Allen-type wrench. Turning the screw in (clockwise) should increase the duty cycle; turning the screw out (counterclockwise) should decrease the duty cycle.
6. Adjust the idle mixture screw on the mixer until a reading of 35-55% is reached for the FTV Duty Cycle in Closed Loop Idle (Figure 41). If engine idle performance is unstable, screw the idle screw in slightly to see if stability is obtained, but in no case should duty cycle exceed 60%.

AFR CONTROL	LP	
LP Fuel Cntrl	Open-Loop	← Closed Loop
Duty Cycle %	0.00	← Duty Cycle%
LP Adapt Offset	0.00	
O2 Value	1.00	Phi
AFR CONTROL	Gasoline	
Gasoline Fuel Cntrl	Open-Loop	
O2 Value	1.00	Phi
Gasoline Adapt Factor	0.00000	
INJ 1 mg per Injection		

Figure 41. FTV Duty Cycle Percentage Displayed on Service Tool

7. Use the accelerator pedal to increase rpm above idle momentarily (rev the engine) then release the pedal to return to idle rpm. The duty cycle setting should remain within the adjustment range (35-55%). Place your thumb over the adjustment port for a more accurate reading by preventing air from leaking past the mixture adjustment screw, which may cause the duty cycle to decrease.
8. If the FTV duty cycle reading is above 55% adjust the idle adjustment screw outward and re-check the duty cycle reading. Continue to do this until the FTV duty cycle reading is within the optimum range (35-55%) and engine rpm is stable. DO NOT adjust the screw so far outward that the tamper proof cap cannot be installed. A duty cycle measurement at Closed Loop Idle of 25-60% is acceptable if the optimum range of 35-55% cannot be reached through adjustment. If the FTV duty cycle cannot be adjusted below 60%, the mixer is faulty and should be replaced.

NOTE : If the FTV Duty Cycle reading is NOT between 25-60%, check for possible vacuum leaks, manifold leaks, or a faulty mixer.

9. Turn the ignition key to the OFF position to shut down the engine.
10. Install the tamper proof cap on the idle mixture screw adjustment port using a large pin punch, so that no further adjustments can be made (Figure 42).

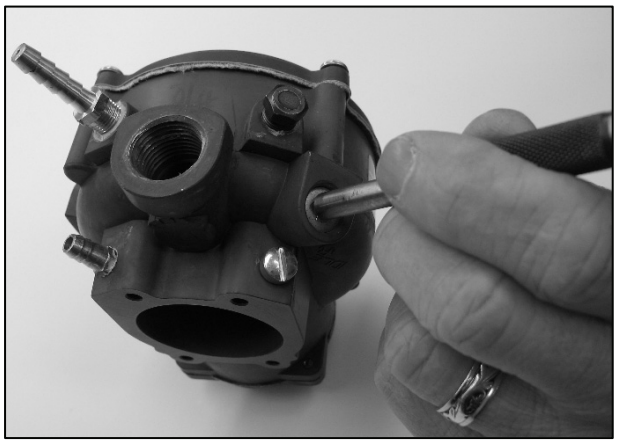
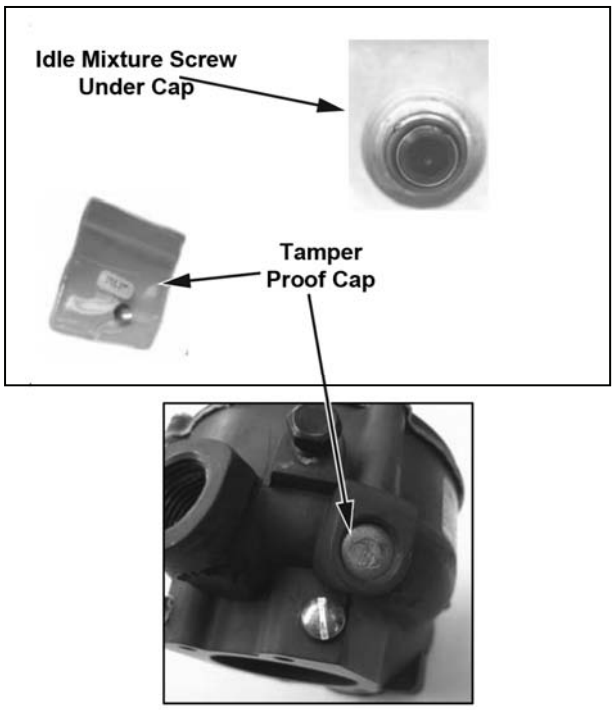


Figure 42. Installing Tamper Proof Cap



Field Adjustment Procedure:

The idle mixture adjustment should only be necessary on a new mixer that does not have the tamper proof cap installed. The method for making the idle mixture adjustment to a running engine is to use the Service Tool software by connecting a laptop computer to the SECM. If you do not have the Service Tool a multimeter capable of measuring duty cycle, such as a Fluke 87 III, can be used. If using a multimeter, connect the meter positive lead to between battery positive and the meter negative to the FTV signal wire. For the Fluke 87, press the "RANGE" button until 4 or 40 appears in the lower right-hand corner of the display. Press the "Hz" button twice so that the percent sign (%) appears on the right-hand side of the display. The multimeter will then read the duty cycle percentage the same as the Service Tool shown in Figure 41.

1. After installing a new mixer, operate the engine Bon LPG fuel. Start the engine and permit it to warm up until the coolant temperature (ECT on Mototune display) is approximately 167°F (75°C).

2. Place the transmission in Neutral.

3. Mototune display parameter LP Fuel Control must display "Closed Loop".

4. Use the Mototune Service Tool to monitor Duty Cycle % on the Mototune display.

5. To adjust the idle mixture screw, use a hex or Allen-type wrench. Turning the screw in (clockwise) should increase the duty cycle; turning the screw out (counterclockwise) should decrease the duty cycle.

6. Adjust the idle mixture screw on the mixer until a reading of 35-55% is reached for the FTV Duty Cycle in Closed Loop Idle (Figure 41). If engine idle performance is unstable screw the idle screw in slightly to see if stability is obtained, but in no case should duty cycle exceed 60%.

7. Use the accelerator pedal to increase rpm above idle momentarily (rev the engine) then release the pedal to return to idle rpm. The duty cycle setting should remain within the adjustment range (35-55%). Place your thumb over the adjustment port for a more accurate reading by preventing air from leaking past the mixture adjustment screw, which may cause the duty cycle to decrease.

8. If the FTV duty cycle reading is above 55% adjust the idle adjustment screw outward and re-check the duty cycle reading. Continue to do this until the FTV duty cycle reading is within the optimum range (35-55%). DO NOT adjust the screw so far outward that the tamper proof cap cannot be installed. A duty cycle measurement at Closed Loop Idle of 25-60% is acceptable if the optimum range of 35-55% cannot be reached through adjustment. If the FTV duty cycle cannot be adjusted below 60%, the mixer is faulty and should be replaced.

NOTE : If the FTV Duty Cycle reading is NOT between 25-60%, check for possible vacuum leaks, manifold leaks, or a faulty mixer.

9. Turn the ignition key to the OFF position to shut down the engine.

10. Install the tamper proof cap on the idle mixture screw adjustment port using a large pin punch, so that no further adjustments can be made (Figure 42).

Parts Description

CA100 Mixer for G424FE Engine

Parts List of CA100 Mixer (Certified)

REF NO	DESCRIPTION	QTY
1	Torx Screws (T-25) #10-24 x 5/8”	4
2	Lockwashers (T-210) #10 SST	4
3	Mixer Cover	1
4	Mixer Spring	1
5	Diaphragm	1
6	Air Valve Assembly	1
7	Gas Valve Cone (part of air valve assembly)	1
8	Mixer Body	1
9	Expansion Plug Cap Ø 1/2” x 1/16” thick (Ø 12.7mm x 27mm)	1
10	Fuel Inlet	1
11	Air Horn Gasket	1
12	Air Horn Adapter 2-1/16” (52.37mm)	1
13	Fillister Head Screws SEMS Lockwasher 10-24 UNC x 5/8”	4
14	Throttle Body Gasket	1
15	Fillister Head Screws SEMS Split Lockwasher #12-24 x 5/8”	4

Exploded View of CA100 Mixer (Certified)

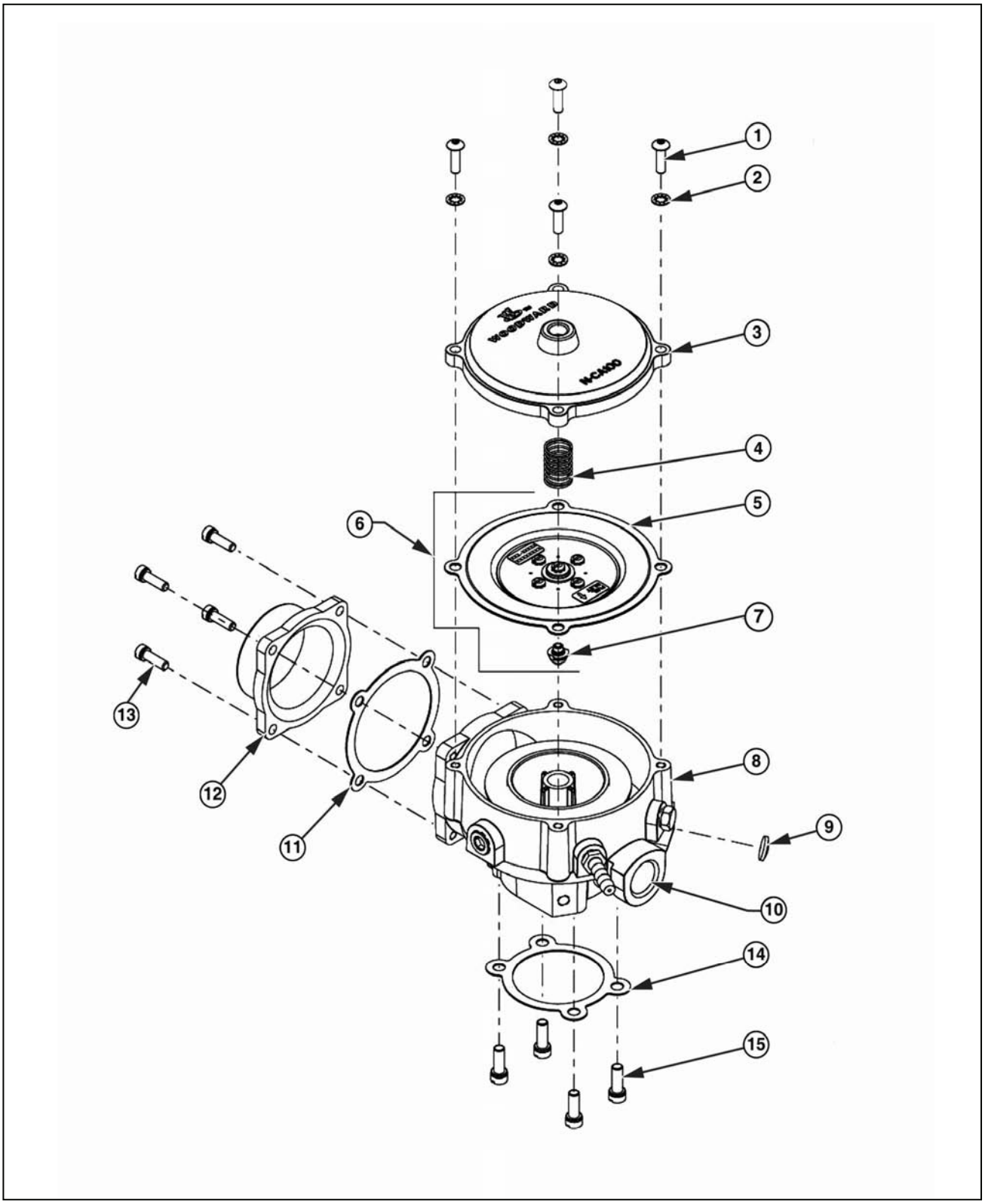


Figure 44. CA100 Certified Mixer Exploded View

N-2007 Regulator for G424FE Engine

Parts List of N-2007 Regulator (Certified)

REF NO	DESCRIPTION	QTY
1	N-2007 Body	1
2	Diaphragm, Primary Assembly	1
3	Springs, Primary Assembly	2
4	Cover, Primary Assembly	1
5	Spring, Secondary Seat, Red	1
6	Dowel Pin Ø 0.094” x 1” L (Ø 2.39mm x 25.4mm L) Hardened Steel	1
7	Diaphragm, Secondary Assembly	1
8	Lever, Secondary	1
9	Seat, Secondary	1
10	Valve Primary	1
11	Fillister Head Screws SEMS Split Lockwasher #12-24 x 5/8”	6
12	Pan Head Screw SEMS Ext. Tooth Lockwasher #12-24 x 1/4”	1
13	Body Gasket	1
14	Back Plate	1
15	O-ring, Size 107 GLT Viton®	1
16	Bottom Plate Gasket	1
17	Plate Cover	1
18	Fillister Head Screws SEMS Split Lockwasher #12-24 x 1-3/8”	6
19	Hex Head Screws SEMS Split Lockwasher 1/4-20 x 5/8”	4
20	Plug, Socket Head Pipe (T-086)	1
21	Cover, Secondary Diaphragm	1
22	Lockwasher, Int. Tooth (T-210) #8 SST	6
23	Torx Screws (T-15) #8-32 x 5/8”	6

Exploded View of N-2007 Regulator (Certified)

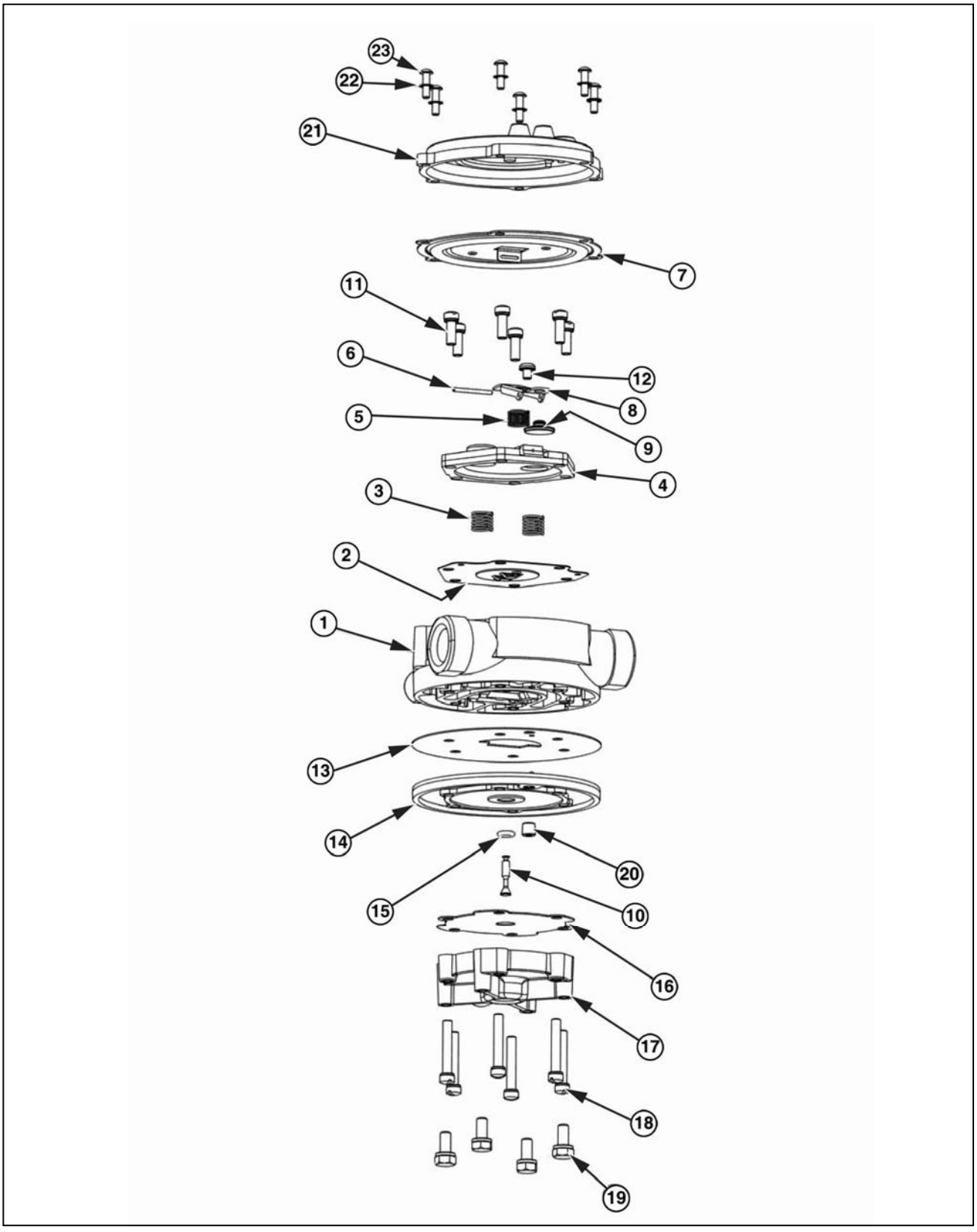


Figure 46. N-2007 Certified Regulator Exploded View

G424F LPG System Inspection and Repair

Removal and Installation

⚠ WARNING – PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**

- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**

- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

⚠ CAUTION

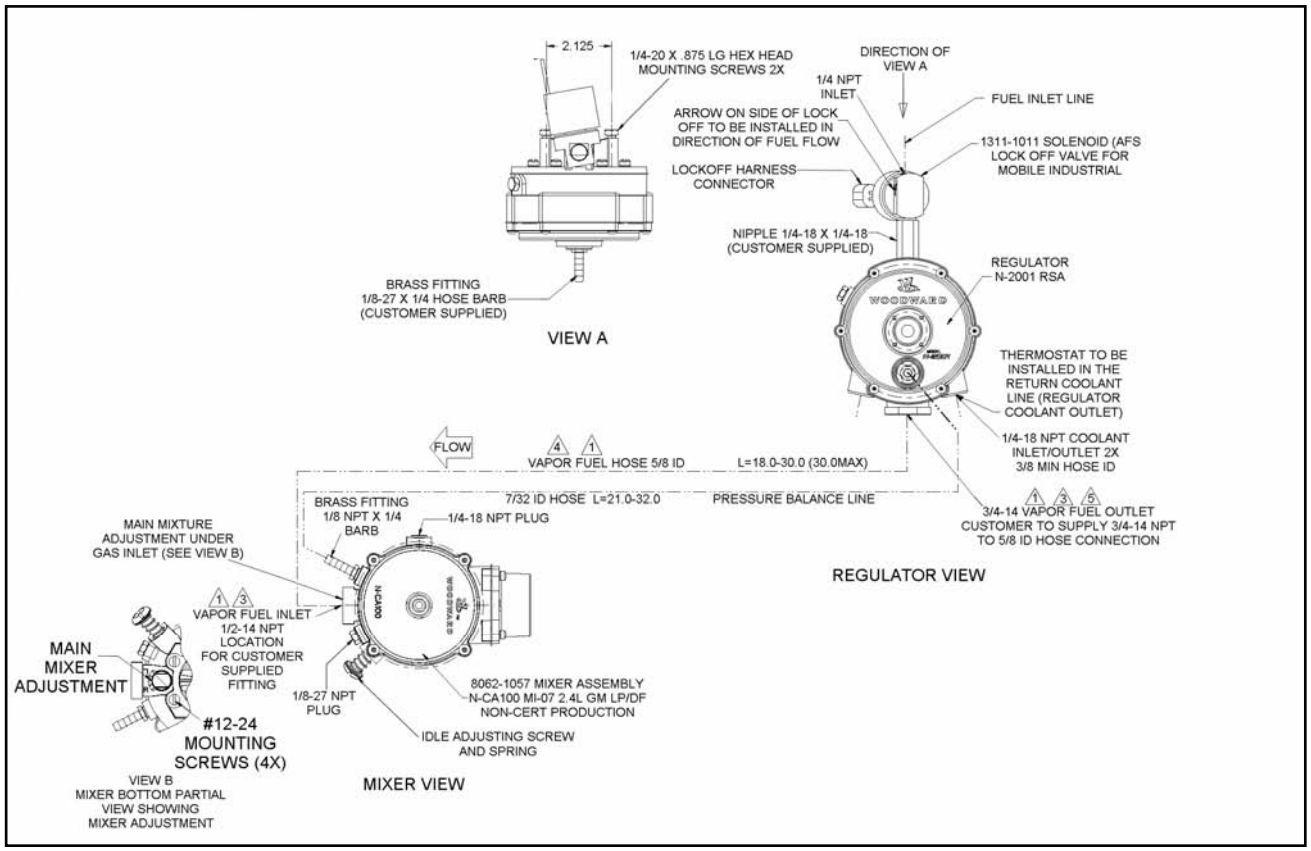
The regulator/converter and mixer are part of a certified system complying with EPA and CARB 2007 requirements. Only trained, certified technicians should perform disassembly, service or replacement of the regulator/converter or mixer.

G424F Fuel System Connections

NOTE: Preferred mounting of regulator is off engine.

Hose Specifications

Vacuum hose to comply to SAE 1403 Type I or SAE J30 R7 R8 / EPDM textile reinforced / -40° F to +257° F (-40° C +125° C / Inside Diameter: 7/32" (5.56mm)


2.125
1/4-20 X .875 LG HEX HEAD MOUNTING SCREWS 2X
DIRECTION OF VIEW A
1/4 NPT INLET
FUEL INLET LINE
ARROW ON SIDE OF LOCK OFF TO BE INSTALLED IN DIRECTION OF FUEL FLOW
1311-1011 SOLENOID (AFS LOCK OFF VALVE FOR MOBILE INDUSTRIAL
LOCKOFF HARNESS CONNECTOR
NIPPLE 1/4-18 X 1/4-18 (CUSTOMER SUPPLIED)
REGULATOR N-2001 RSA
BRASS FITTING 1/8-27 X 1/4 HOSE BARB (CUSTOMER SUPPLIED)
VIEW A
THERMOSTAT TO BE INSTALLED IN THE RETURN COOLANT LINE (REGULATOR COOLANT OUTLET)
1/4-18 NPT COOLANT INLET/OUTLET 2X 3/8 MIN HOSE ID
FLOW
4 1
VAPOR FUEL HOSE 5/8 ID
L=18.0-30.0 (30.0MAX)
BRASS FITTING 1/8 NPT X 1/4 BARB
7/32 ID HOSE L=21.0-32.0
1/4-18 NPT PLUG
PRESSURE BALANCE LINE
1 3 5
3/4-14 VAPOR FUEL OUTLET CUSTOMER TO SUPPLY 3/4-14 NPT TO 5/8 ID HOSE CONNECTION
MAIN MIXTURE ADJUSTMENT UNDER GAS INLET (SEE VIEW B)
REGULATOR VIEW
1 3
VAPOR FUEL INLET 1/2-14 NPT LOCATION FOR CUSTOMER SUPPLIED FITTING
MAIN MIXER ADJUSTMENT
1/8-27 NPT PLUG
8062-1057 MIXER ASSEMBLY N-CA100 MI-07 2.4L GM LP/DF NON-CERT PRODUCTION
IDLE ADJUSTING SCREW AND SPRING
#12-24 MOUNTING SCREWS (4X)
VIEW B MIXER BOTTOM PARTIAL VIEW SHOWING MIXER ADJUSTMENT
MIXER VIEW

DWG NO 5555-1243

Figure 27. Hose Connections for Non-Certified Systems

DIAGRAM NOTES

1 Only one 90° fitting permissible on vapor fuel line between mixer and regulator

3 Vapor fuel fittings (regulator and mixer) must have minimum ID of 0.46" (11.68mm)

4 Vapor hose length to be as short as possible and have no restrictions for best regulator performance

5 Fuel outlet must be positioned vertically in the down position

Removal and Installation of N-2001 LP Regulator/Converter

Follow the procedures below for removal and reinstallation of the N-2001 regulator.

N-2001 Removal Steps

Refer to Figure 29.

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.

2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.

3. Remove the fuel inlet line (1) from the lock-off, the two vacuum lines (2) from the branch-tee fitting in the regulator vent and disconnect the lock-off connector (3).

4. Remove the two rear-mounting bolts that hold the regulator to the support bracket. This will permit easier access to the remaining hose clamps.

5. Remove the two cooling lines (4) from the regulator.

NOTE: It will be necessary to either drain the coolant system or clamp off the coolant lines as close to the regulator as possible to avoid a coolant spill when these lines are disconnected.

6. Remove the fuel vapor outlet hose (5) from the regulator.

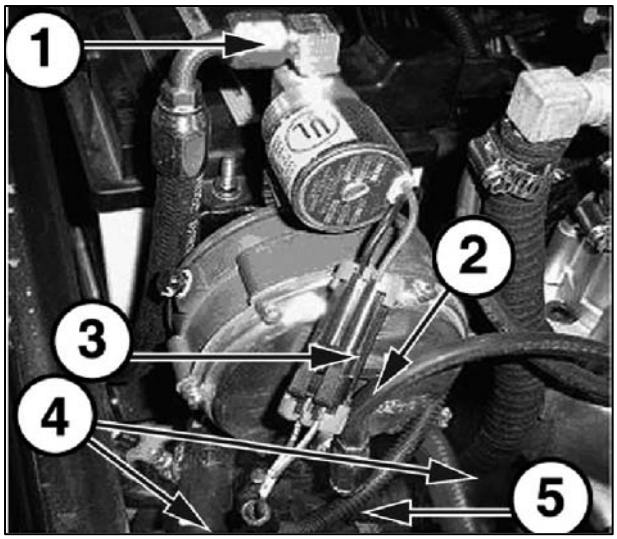


Figure 29. N-2001 Regulator in Non-Certified System

N-2001 Installation Steps

Refer to Figure 29.

1. Install the fuel vapor outlet hose (5) from the regulator.

2. Install the two cooling lines (4) from the regulator.

3. Install the two rear-mounting bolts that hold the regulator to the support bracket. Use a torque wrench and tighten each bolt to 50-60 lbf-in (5.65-6.78 N-m)

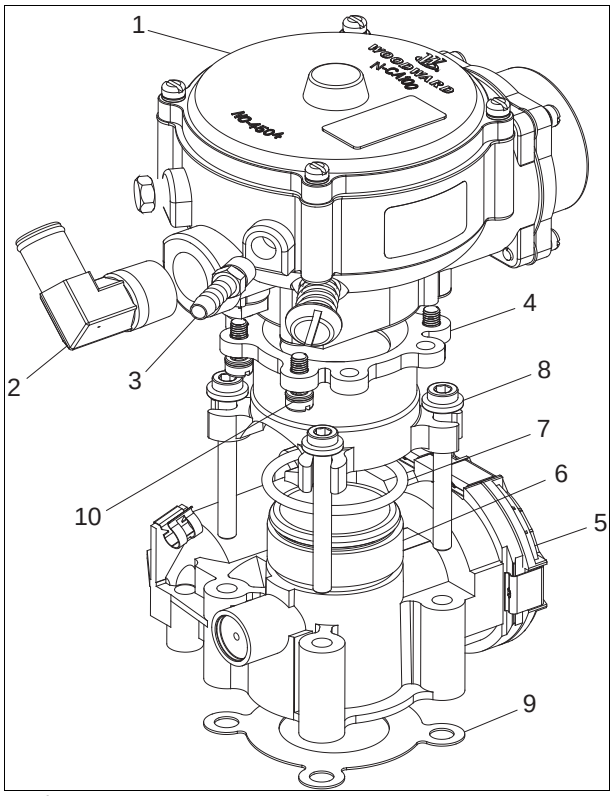
4. Install the fuel inlet line (1) from the lock-off, the two vacuum lines (2) from the branch-tee fitting in the regulator vent and disconnect the lock-off connector (3).

5. Open the liquid outlet valve in the forklift cylinder or fuel storage container.

Removal and Installation of CA100 Mixer for G424F

Follow the procedures below for removal and reinstallation of the CA100 mixer in non-certified systems.

CA100 Mixer Removal Steps



1. Mixer-Non Cert
2. Fitting-To Regulator
3. Fitting-To Regulator
4. Apollo Adapter-ITB, Mixer
5. ITB
6. O-Ring Spacer
7. O-Ring
8. Bolt-ITB.Conn
9. Gasket-ITB
10. Bolt

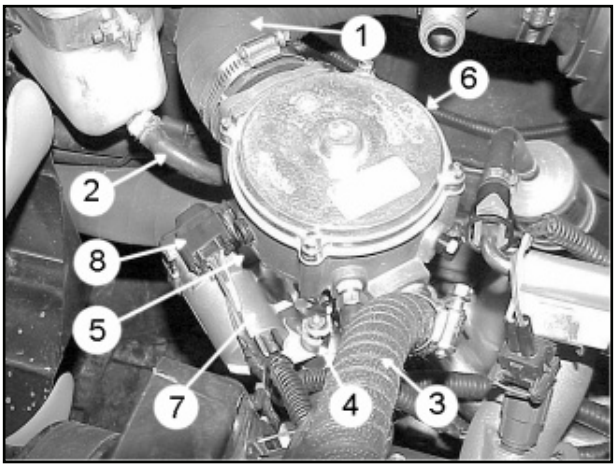


Figure 33. CA100 Mixer in Non-Certified System

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.

2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.

3. Key switch in “OFF” position.

4. Remove the air cleaner hose (1).

5. Remove the vacuum line (2).

6. Remove vapor fuel inlet line (3) from the mixer (6).

7. Disconnect the wires leading to the electronic throttle body by pinching the lock tabs on either side of the wiring harness connector (8).

8. Loosen the four bolts (4) that secure the mixer/adapter/throttle body assembly to the intake manifold.

9. Remove the mixer (6) and the throttle body (7) as an assembly by gently pulling upwards. Take care not to drop anything down the intake manifold.

10. Gently wiggle and pull to separate mixer and adapter from the throttle body. Take note of the adapter orientation on the mixer, as it must be reinstalled correctly for proper fit on the throttle.

11. Remove the four mounting screws that attach the throttle adapter to the mixer.

12. Remove the vapor fuel inlet fitting from the mixer.

CA100 Mixer Installation Steps

1. Install the vapor fuel inlet fitting onto the mixer.

2. Install the four mounting screws that attach the throttle adapter (5) to the mixer. (See **Figure 32**). Torque bolts to 30-40 lbf-in (3.39-4.52 N-m).

3. Position the mixer/adapter assembly onto the throttle body (7), then drop in the four mounting bolts (4) and gently push down on the assembly until it rests on the throttle body. Be careful not to pinch the O-ring. (See Figure 31.)

4. Attach the mixer/throttle body assembly to the intake manifold, making sure gasket is in place. Tighten the four mounting bolts.

5. Connect the wiring harness (8) to the throttle body.

6. Install the vapor fuel inlet line (3) to the mixer.

7. Install the vacuum line (2) to the mixer.

8. Install the air cleaner hose (1).

NOTE : A plastic O-ring spacer and an O-ring are inside the mixer/adapter assembly. Be careful not to lose these items when removing the assembly from the throttle (Figure 31).

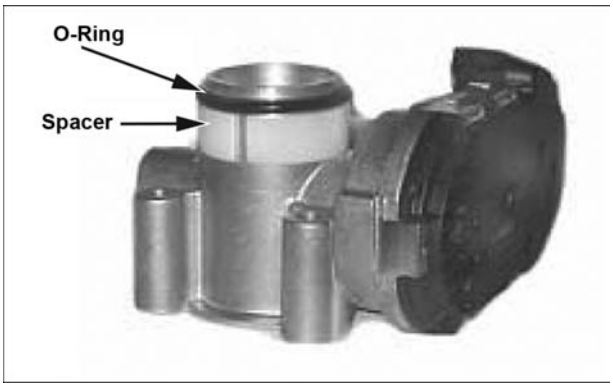


Figure 31. O-Ring and Spacer Within Mixer Adapter Assembly

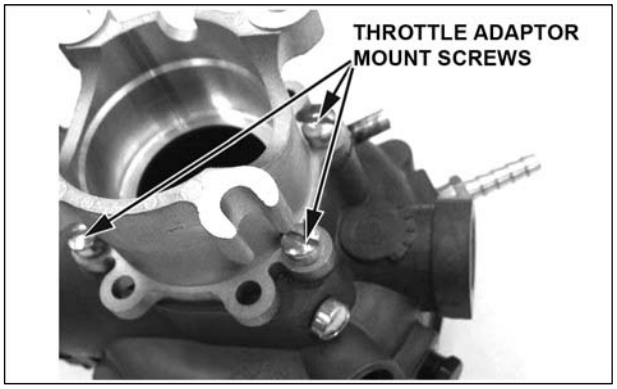


Figure 32. Throttle Adapter Mount Screws

Tests and Adjustments

⚠ WARNING – PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**
- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**
- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

N-2001 Regulator Service Testing

For checking the N-2001 regulator/converter operation, the following tests can be performed. To check the secondary regulation (output) a simple vacuum hand pump can be used to simulate the vacuum signal transmitted from the air/fuel mixer when the engine is running. See listing below for required hardware.

Break-Off Test

Secondary Stage Test Hardware

1. Hand vacuum pump

2. Regulator vapor outlet test fitting 3/4" NPT x 1/4" hose barb

3. Union Tee 1/4" NPT with three 1/4" NPT x 1/4" hose barb

4. Vacuum hose

5. 0-3" WC Magnehelic gauge (inches of water column)

Secondary Stage (Break-Off) Test

1. Connect the vacuum pump, the Magnehelic gauge and the regulator vapor outlet to the Union Tee fitting (Figure 30). Make sure there is no leakage at any of the fittings.

2. Using the vacuum pump slowly apply enough vacuum to measure above -2" WC on the gauge. This vacuum signal opens the secondary valve in the N-2001 regulator/converter.

3. Release the vacuum pump lever and you will see the gauge needle start falling back toward zero. When the pressure drops just below the specified break-off pressure (-1.2 " WC) of the secondary spring, the needle should stop moving.

4. At this point the secondary valve should close. If the secondary valve seat or the secondary diaphragm is leaking the gauge needle will continue to fall toward zero (proportional to the leak size). An excessively rich air/fuel mixture can be caused by a secondary valve seat leak and the regulator should be replaced.

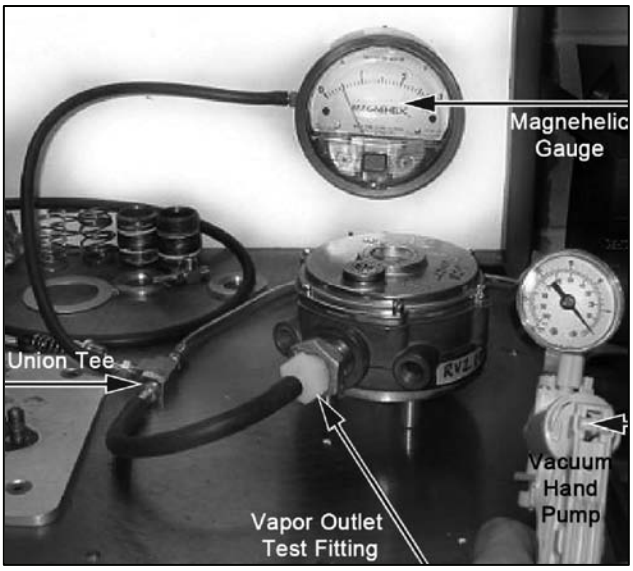


Figure 30. Secondary Stage Test Connection

Pressure Test

Primary Stage Test Hardware

1. Hand vacuum pump

2. Regulator fuel inlet test fitting 1/4 NPT standard air coupling)

3. Test gauge fitting (1/4" NPT X 1/4" hose b)

4. Vacuum hose or vinyl tubing

5. 0-60" WC Magnehelic gauge (inches of water column)

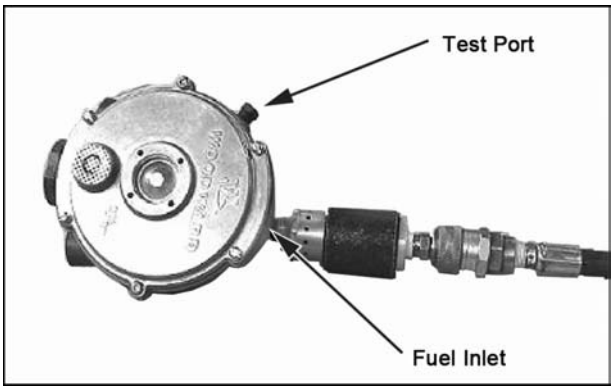


Figure 31. Primary Stage Test Connection

Primary Stage Pressure Test

1. Remove the primary test port plug from the side of the regulator and install the 1/16" NPT hose barb fitting (Figure 31).

2. Connect a compressed air line (shop air ~100 psi) to the liquid propane fuel inlet of the N-2001 regulator (Figure 31).

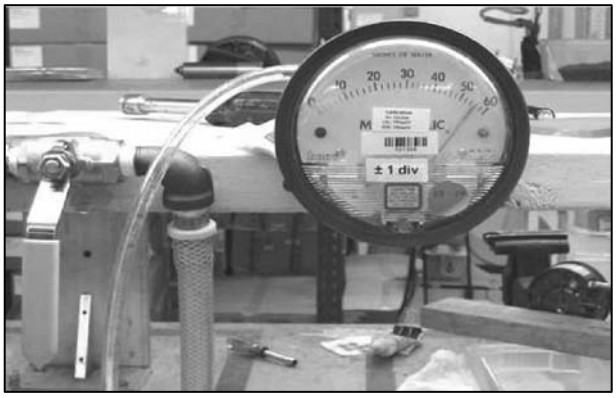


Figure 32. Magnehelic Gauge Connection to Hose Barb

3. Apply compressed air, wait for air to exit the hose barb in the test port, and then connect the Magnehelic gauge (Figure 32) to the hose barb using the vacuum hose or vinyl tubing. This prevents the gauge from reading maximum pressure due to the large velocity of compressed air entering the primary chamber.

4. Make sure there is no leakage at any of the fittings. The static pressure should read between 40-60" WC on the Magnehelic gauge and maintain a constant pressure for 60 seconds.

5. If the pressure reading begins to increase, a leak is most likely present at the primary valve, either the primary valve o-ring or the valve itself. If a leak is present the regulator should be replaced.

6. If the pressure begins to decrease, the secondary seat is probably not making an adequate seal and is leaking. The regulator should be replaced.

7. If the test is successful, re-install the primary test port plug and check the fittings for leaks. See Chapter 5 for installation of the N-2001 regulator.

NOTE : The N-2001 primary stage pressure can also be tested at idle on a running engine. The N-2001 primary pressure should be between
40 inH20 (99.635 mbar) and 55 inH20 (136.999 mbar) at 750 rpm, idle.

AVV (Air Valve Vacuum) Testing

Purpose of Test

Check for excessive or inadequate pressure drop across CA100 mixer.

AVV Test Hardware

1. Union Tee fitting, 1/4" (6.35mm) NPT with three 1/4" (6.35mm) NPT x 1/4" (6.35mm) hose barbs
2. Vacuum hose
3. 0-20" H2O differential pressure Magnehelic gauge

AVV Test

1. Install Union Tee fitting in the hose between the FTVs and the AVV fitting. Connect this fitting to the low pressure port of the Magnehelic gauge (Figure 37).

2. Leave high pressure port of the Magnehelic gauge exposed to ambient pressure (Figure 37).

3. With the engine fully warmed up and running at idle (750 rpm) place the transmission in Neutral. The AVV should be between 5" and 8" H2O of pressure vacuum.

4. If the measured pressure drop is excessively high, check for sticking or binding of the diaphragm air valve assembly inside the mixer. Replace mixer if necessary.

5. If the measured pressure drop is low, check for vacuum leaks in the manifold, throttle, mixer, TMAP sensor and attached hoses.

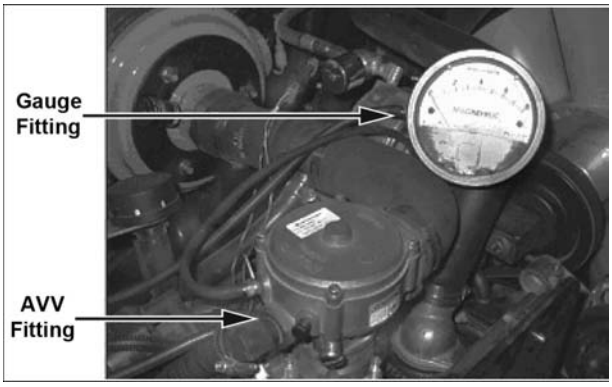


Figure 37. Magnehelic Gauge Connection

Ignition Timing Adjustment

With the MI-07 system, ignition-timing advance is controlled by the SECM.

Connection of the MI-07 Service Tool

To use the Service Tool, a USB (Universal Serial Bus) to CAN (Controller Area Network) communication adapter by KVaser will be required along with a Crypt Token (Figure 38). The Crypt Token acts as a security key allowing the laptop to retrieve the necessary data from the SECM.

1. Install the Crypt Token in an available USB port in the computer (Figure 39).

2. With the ignition key in the OFF position, connect the KVaser communication cable from a second USB port on the computer to the CAN communications cable on the engine. (*If your laptop computer does not have a second USB port an appropriate USB hub will need to be used).

3. Connect a timing light to the engine.

4. Turn the ignition key to the ON position (Do Not Start the Engine).

5. Launch the MotoView program on your computer and open the Service Tool display (Figure 40).



Figure 38. KVaser Communication Adapter

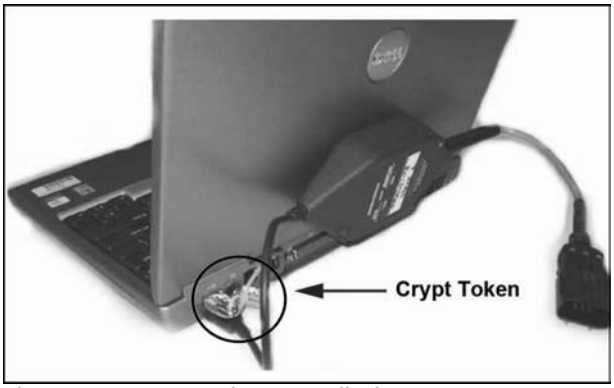


Figure 39. Crypt Token Installed on Laptop



Figure 40. Opening the Service Tool Display

Idle Mixture Adjustment

NOTE : Be sure engine is fully warm (ECT>167°F [75°C]) before performing the idle mixture adjustment.

G424F LP Fuel Systems with O2 Sensor

Idle Adjustment

1. Install mixer and a UEGO or HEGO sensor. (A UEGO sensor should be used when desired phi settings are not at stoichiometric.)

2. After the mixer is installed, start and warm up the engine to normal operating temperature (ECT>167°F [75°C]). Also ensure that the vehicle drive train and hydraulic systems are at normal operating temperatures per vehicle manufacturer recommendations.

3. Allow the engine to reach steady state at idle.

4. While monitoring the output of the UEGO or HEGO sensor adjust the idle screw using a standard screwdriver until the desired phi reading is achieved (phi = 1.00 to 1.01 is optimal). To make the mixture richer, turn the screw clockwise; to make the mixture leaner, turn the screw counter-clockwise.

5. Rev the engine to take it off of idle and let it return to idle.

6. Once the engine has reached steady state at idle, verify the phi reading. Adjust further as needed.

Power Valve Adjustment

1. The power valve should only be adjusted after the idle screw has been adjusted properly. The engine and vehicle drive train and hydraulics should also be at normal operating temperatures.

2. Apply a load to the engine while the engine is operating above idle speed. Torque converter stall is the preferred operating mode for this test. If a torque converter speed test cannot be performed, the engine can be run at another speed (max governor), but a load must be applied by using hydraulics.

NOTE : While adjusting the power valve, do not hold engine at load point for longer than 5-10 seconds. Holding for a longer period of time will cause the fuel temperature to drop, which could adversely affect the power valve setting.

3. Monitor the output of the UEGO or HEGO sensor while the engine is at the higher speed with the load applied (phi = 1.00 to 1.05 is optimal).

4. If the phi reading is not at the desired level, bring the engine back to idle and adjust the power valve.

5. Bring the engine back to the higher speed with a load applied and verify the power valve setting. Adjust further as needed.

6. Once the power valve is set, bring the engine back to idle and verify the idle screw setting.

G424F LP Fuel Systems Without O2 Sensor

Idle Adjustment

1. After the mixer is installed, start and warm up the engine to normal operating temperature (ECT>167°F [75°C]). Also ensure that the vehicle drive train and hydraulic systems are at normal operating temperatures per vehicle manufacturer recommendations.

2. Allow the engine to reach steady state at idle.

3. With the idle screw completely tightened clockwise, use a standard screwdriver to adjust the idle screw counterclockwise until a minimum average MAP value has been reached. The MAP value is displayed on the Service Tool screen.

Power Valve Adjustment

1. The power valve should only be adjusted after the idle screw has been adjusted properly. The engine and vehicle drive train and hydraulics should also be at normal operating temperatures.

2. Apply a load to the engine while the engine is operating above idle speed. Torque converter stall is the preferred operating mode for this test. If a torque converter speed test cannot be performed, the engine can be run at another speed (max governor), but a load must be applied by using hydraulics.
The power valve should be adjusted to obtain maximum torque converter stall speed.

NOTE : While adjusting the power valve, do not hold engine at load point for longer than 5-10 seconds. Holding for a longer period of time will cause the fuel temperature to drop, which could adversely affect the power valve setting.

3. Once the power valve is set, bring the engine back to idle and verify the idle screw setting.

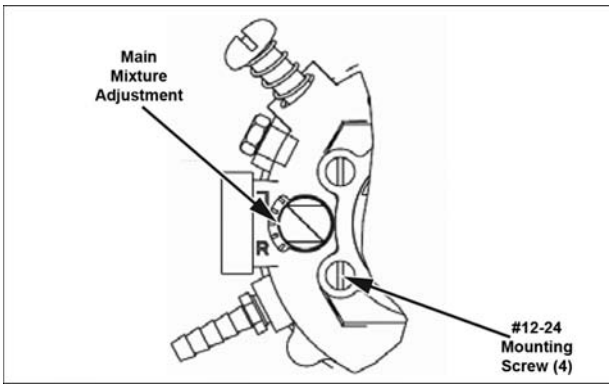


Figure 43. Main Mixture Adjustment on Bottom of Mixer (partial view)

Parts Description

CA100 Mixer for G424F Engine

Refer to **Figure 45** exploded view on facing page.

REF NO.	DESCRIPTION	QTY
1	Screws 10-24 x 5/8” T-25 Button Head SEMS	4
2	Mixer Cover	1
3	Mixer Spring	1
4	Diaphragm	1
5	Gas Valve Cone (part of air valve assembly)	1
6	Mixer	1
7	Throttle Body Gasket	1
8	Screws 12-24 x 5/8” Fillister Head SEMS	8
9	Air Horn Adapter	1
10	Air Horn Gasket	1

Parts List for CA100 Mixer

Exploded View

CA100 Mixer

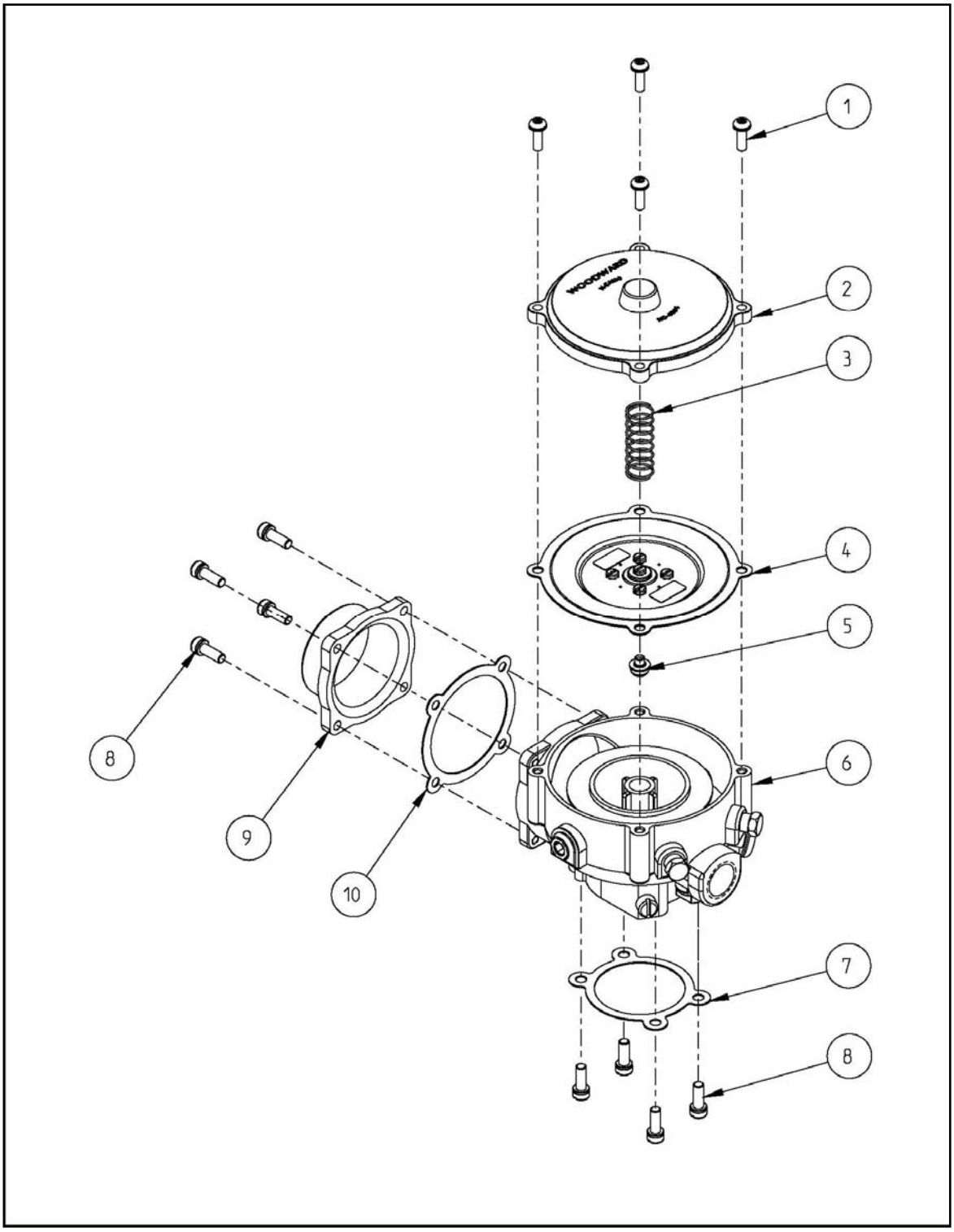
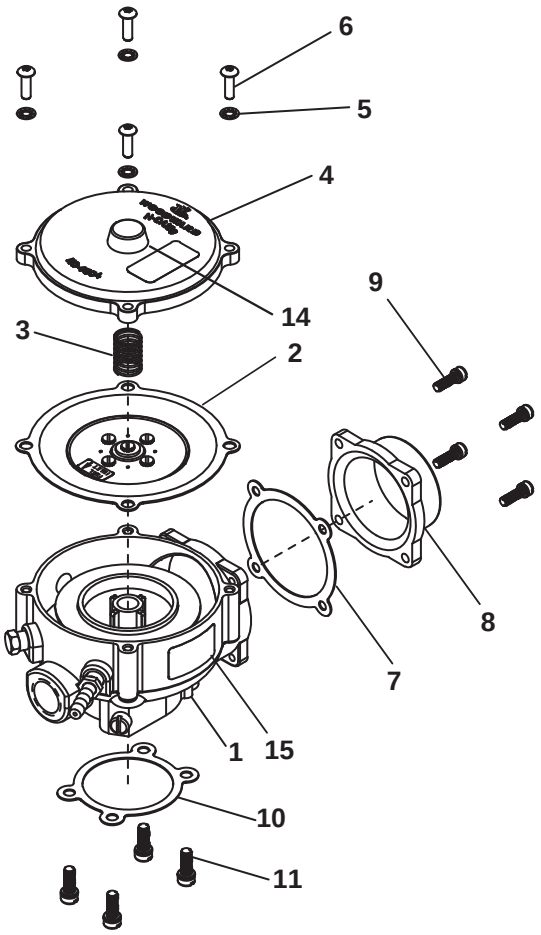
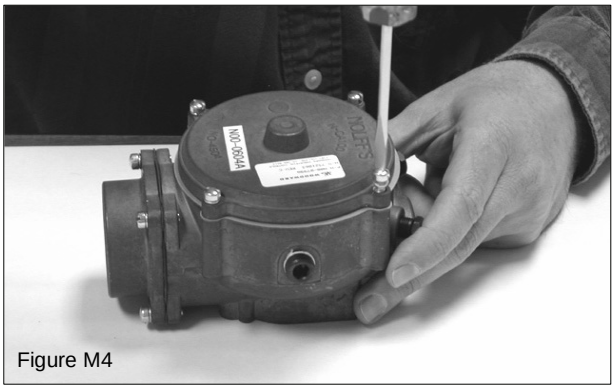


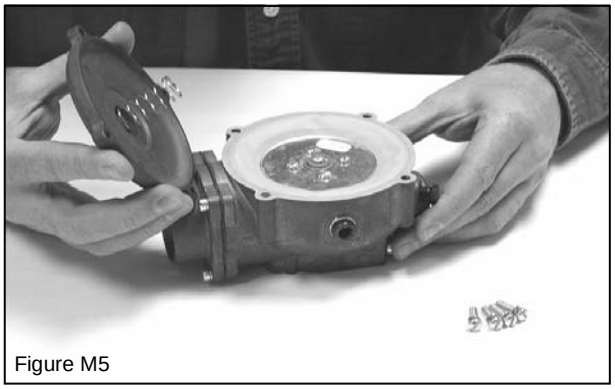
Figure 44. CA100 Non-Certified Mixer Exploded View



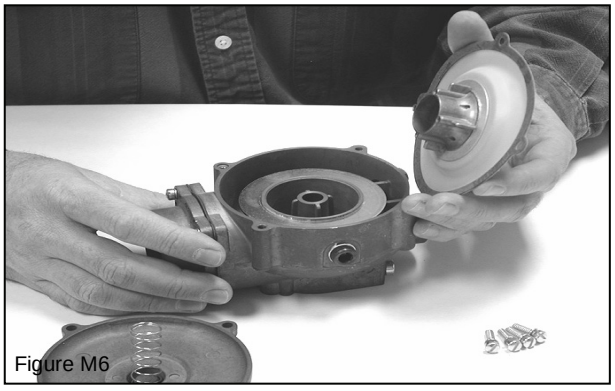
(1) BODY (2) VALVE (3) SPRING (4) COVER
(5) WASHER (6) SCREW (7) GASKET (8) ADAPTER
(9) SCREW (10)GASKET (11) SCREW


Figure M4

1. With the mixer/adapter assembly removed from the engine, and the throttle adapter removed from the mixer, remove the four cover retaining screws from the top of the mixer (Figure M4).


Figure M5

2. Gently remove the diaphragm cover from the top of the mixer. Take care not to loose the air-valve spring shown in (Figure M5).


Figure M6

3. Remove the air-valve assembly from the mixer as shown in (Figure M6).

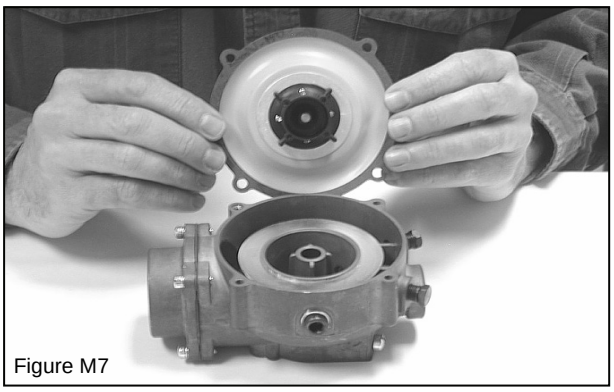


Figure M7

4. Clean the heavy end deposits from the mixer body with solvent. Be sure the mixer body is completely dry before installing the new air-valve assembly. Replace the air-valve assembly as shown (Figure M7).

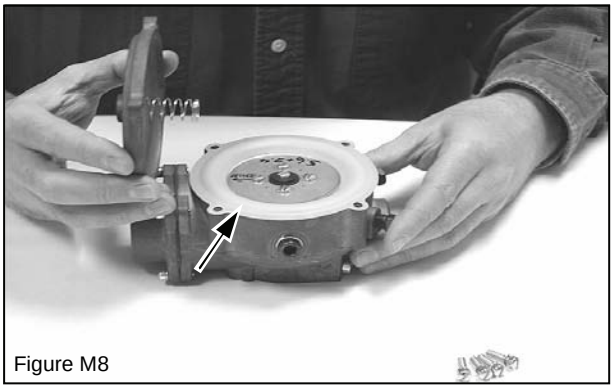


Figure M8

5. Place the alignment mark on top of the air valve assembly toward the fuel inlet of the mixer; this places the small notches in the fuel metering valve (fuel cone) inline with the fuel inlet and the large notches of the fuel metering valve “cone”, perpendicular to the fuel inlet of the mixer. Now reinstall the air-valve spring and diaphragm cover (Figure M8).

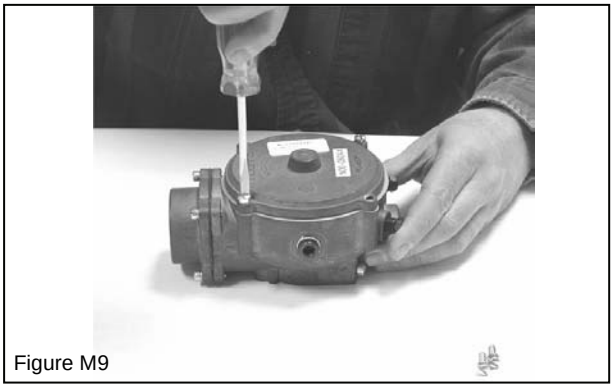


Figure M9

6. Tighten the cover fastners and reinstall the mixer on the engine (Figure M9).

CA100 Disassembled Service

1. Clean the air valve assembly with soap and warm water to remove heavy-end deposits. Inspect the fuel metering valve and sealing ring for wear. Replace worn components as necessary.

Replace all gaskets before assembly.

Clean the mixer body (casting) with a parts cleaning solvent. Be sure to remove all seals and gaskets before cleaning the casting with solvent. Make sure all parts are completely dry before re-assembly.

NOTE
For re-assembly of the CA100 reverse the disassembly steps.

WARNING
DO NOT spray car carburetor cleaner or solvent into the mixer while installed on the engine. These chemicals may damage the oxygen sensor and cause pre-mature failure of the catalytic muffler.

N-2001 Regulator for G424F Engine

Refer to Figure 47 exploded view on facing page.

Parts List
N-2001-RSA Regulator

REF NO.	DESCRIPTION	QTY
1	Cover Screws 8-32 x 5/8” SEMS	4
2	Torx Screws (T-15) 8-32 x 5/8” Tamper Resistant	2
3	Lockwasher #8 Internal Tooth	2
4	Secondary Cover	1
5	Secondary Diaphragm Assembly	1
6	Pan Head Screw 10-24 x 1/4” w/Star Washer	1
7	Secondary Lever	1
8	Secondary Valve	1
9	Secondary Lever Fulcrum Pin	1
10	Red Secondary Spring	1
11	Pilot Valve Lever	1
12	Pilot Valve Lever Fulcrum Pin	1
13	Internal Hex Head Set Screw 8-32 x 1/4”	1
14	Cover Screws 12-24 x 5/8” SEMS	6
15	Primary Diaphragm Cover	1
16	Primary Regulator Springs	2
17	Primary Diaphragm Assembly	1
18	1/8 NPT Hex Pipe Plug Fitting	1
19	Body Assembly	1
20	Body Seal O-ring	1
21	Body Gasket	1
22	Regulator Back Plate	1
23	Primary Seal O-Ring	1
24	Primary Regulator Valve	1
25	Cover Screws 12-24 x 5/8” SEMS	6
26	Inlet Seal O-Ring	1
27	Inlet Plug	1
28	Hex Head Screws 1/4-20 UNC-2A x 5/8” SEMS	2

Exploded View
N-2001-RSA Regulator

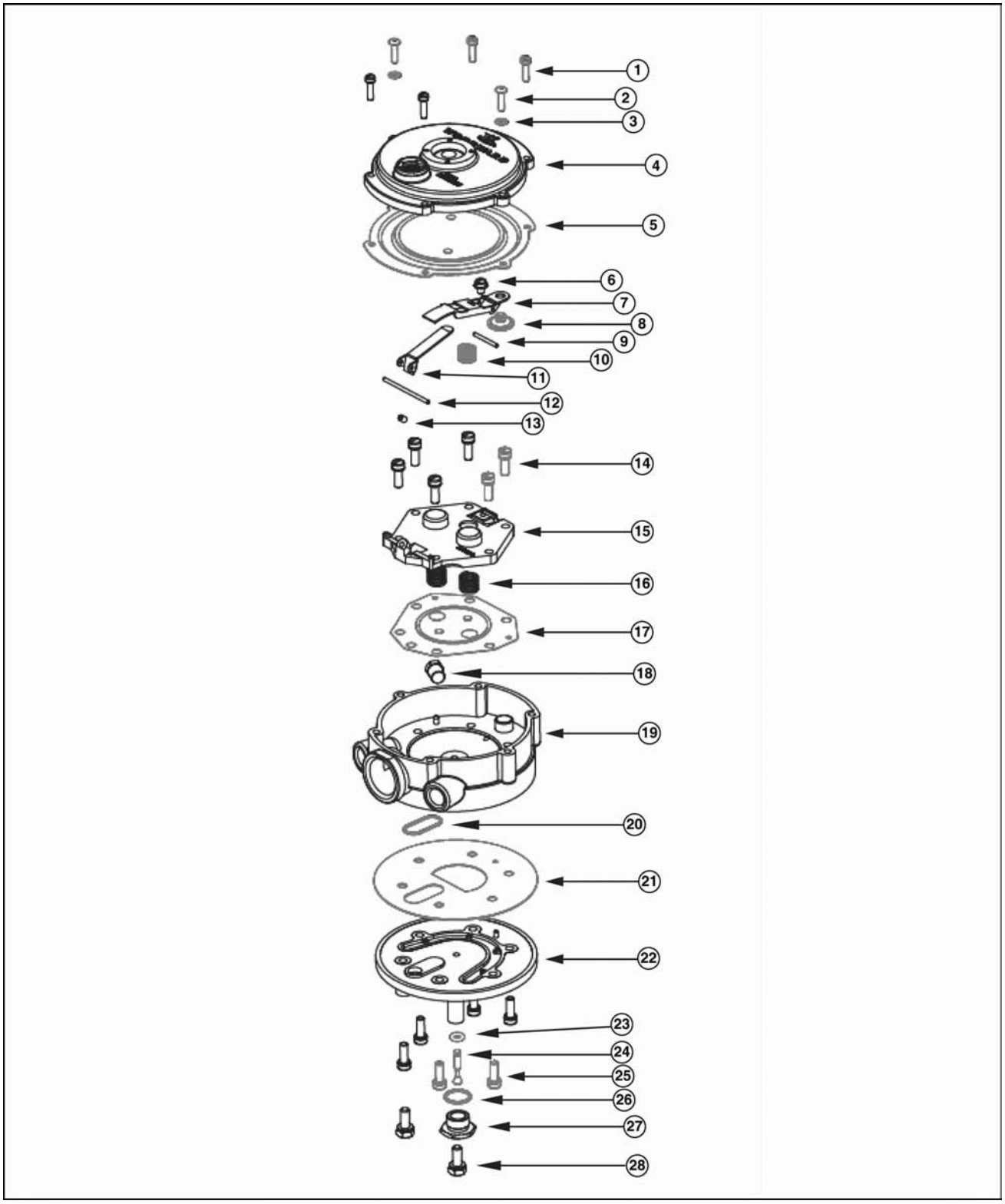


Figure 47. N-2001 Regulator Exploded View

N2001 Regulator Disassembly Steps:

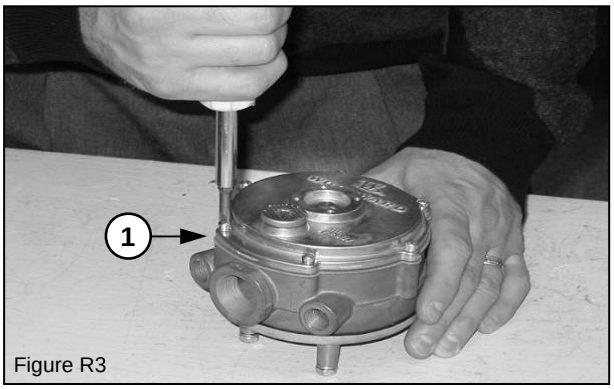


Figure R3

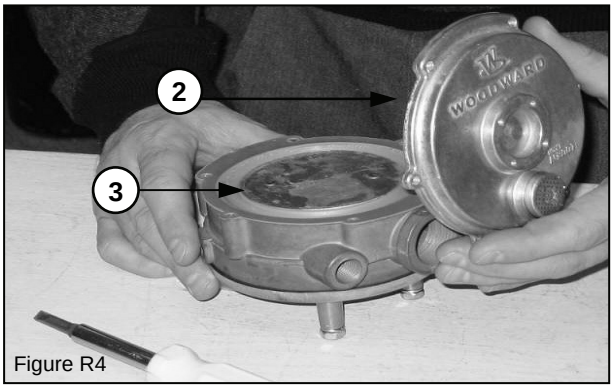


Figure R4

1. Remove the six secondary cover screws (1), the secondary cover (2) and the secondary diaphragm (3).

2. Remove the six primary diaphragm cover screws (4) and the primary cover assembly (5).

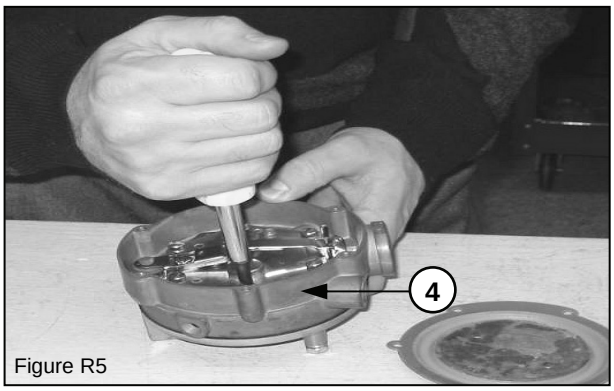


Figure R5

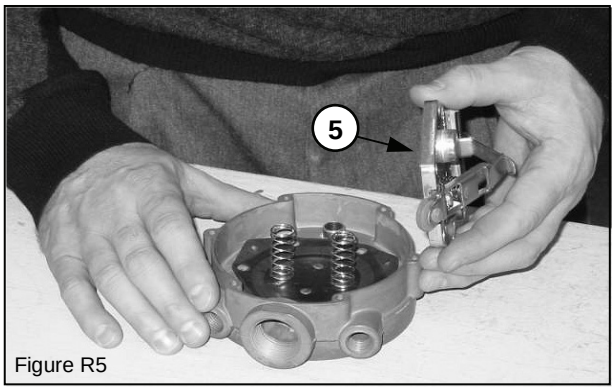
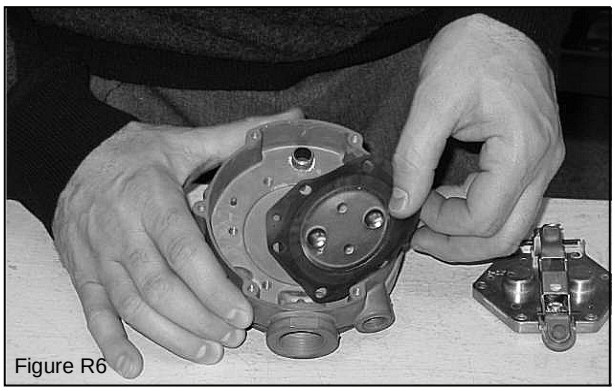


Figure R5

Remove the six primary diaphragm cover screws (4) and the primary cover assembly (5).


Figure R6

Remove the primary diaphragm by sliding the diaphragm to one side, releasing the primary valve pin (Figure R6).

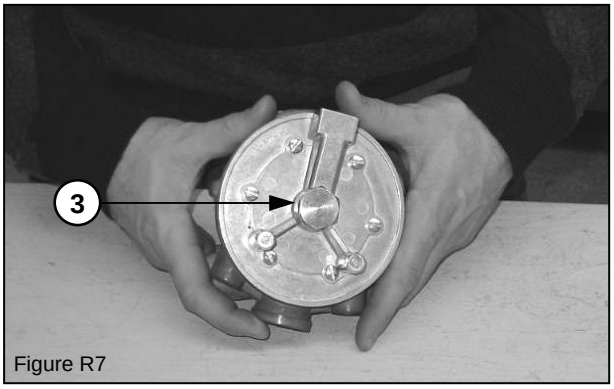


Figure R7

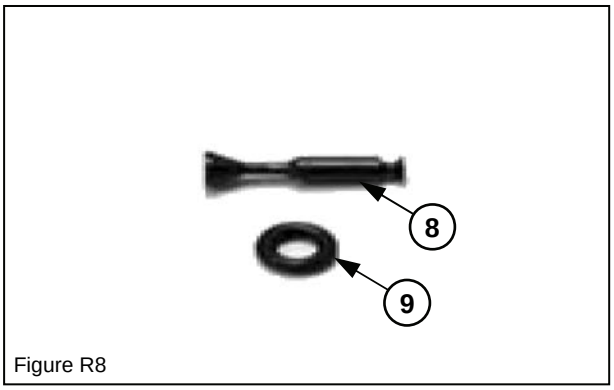
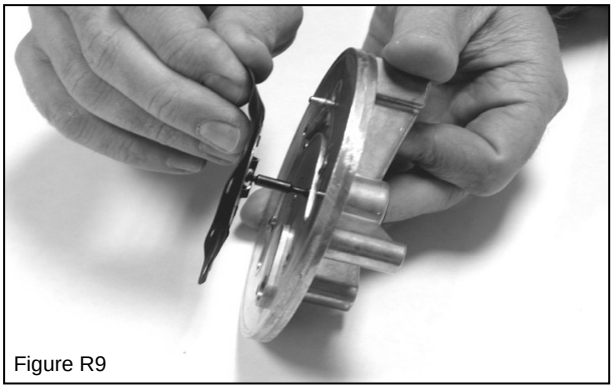
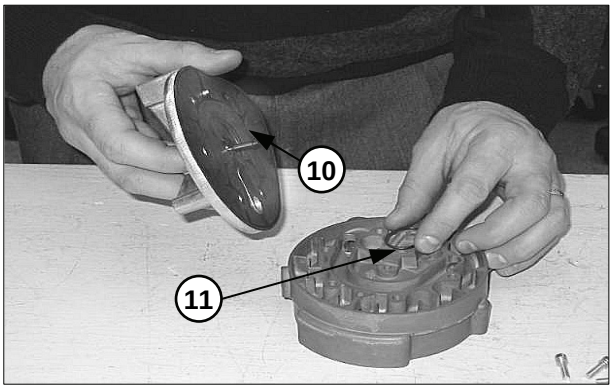


Figure R8


Figure R9

Turn the regulator body over with the rear fuel inlet plate facing up. Remove the primary valve access plug (7), the primary valve (8) and the primary valve o-ring seal (9). ***The primary valve goes through the inlet plate, then through the body assembly and is retained by the primary diaphragm (Figure R9).***



6. Remove the body gasket (10), body o-ring seal (11) and the fuel inlet plate, exposing the fuel inlet expansion chamber and the coolant passage.

NOTE
For re-assembly of the N2001 regulator/converter, reverse the steps for disassembly. Tighten all fasteners to recommended torque values and test the regulator before installing in the vehicle. Torque primary cover screws to (40-50 inch lbs.), secondary cover screws to (15-18 inch lbs.).

N2001 Disassembled Service

1. Clean the primary and secondary valves with soap and warm water to remove heavy-end deposits. Inspect the valve seats and o-rings for wear. Replace worn components as necessary.

2. Clean the primary and secondary diaphragms with soap and warm water. Inspect for wear, tears or pinholes and deformations that may cause leaks or poor performance of the regulator/converter.

3. Replace the body gasket of the coolant chamber and body o-ring seal when servicing the N2001 to avoid coolant leaks from the fuel expansion chamber to the coolant passage.

4. Clean the regulator body (casting) with a parts cleaning solvent. Be sure to remove all seals and gaskets before cleaning the casting with solvent.

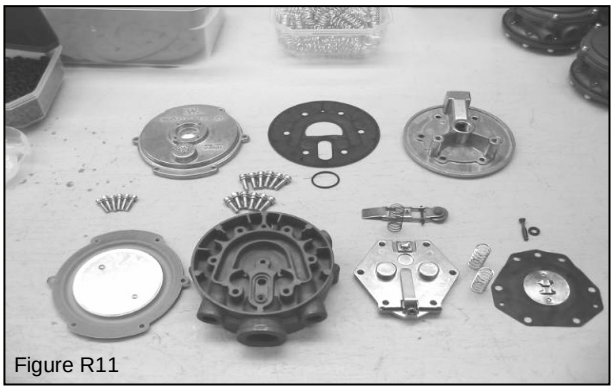


Figure R11

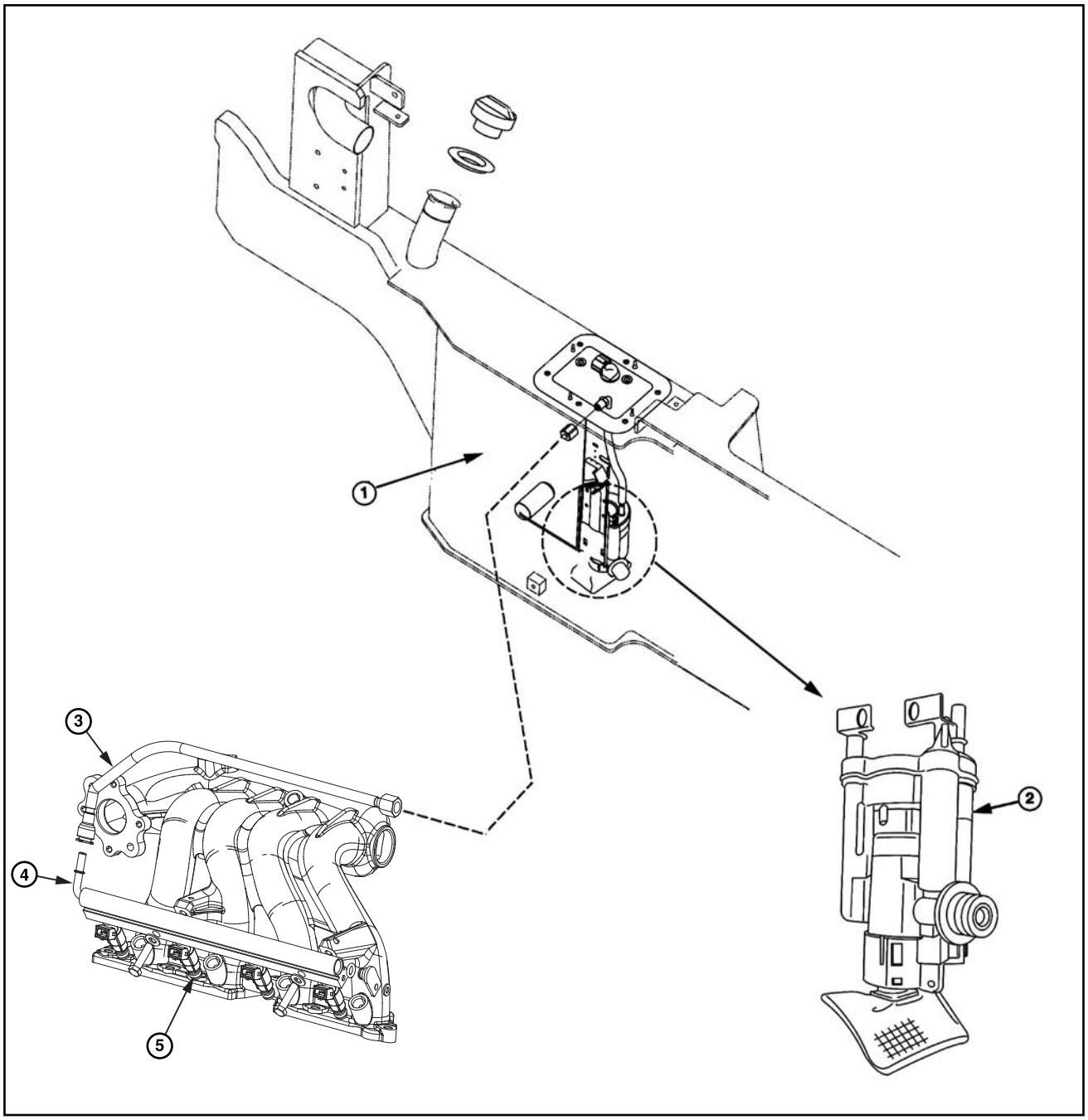
5. Make sure all parts (Figure R11) are completely dry before re-assembly.

Chapter 7. MPI GASOLINE FUEL DELIVERY SYSTEM

Specification

Items	Specification	
Fuel Retrun System	Type	Returnless
Fuel Filter	Type	High pressure type (built in Fuel Pump Assembly)
Fuel Pressure Regulator	Type	Built in fuel pump assembly
	Regulated Fuel Pressure	350 kPa (3.5kg/cm², 49.8psi)
Fuel Pump	Type	Electrical, in-tank type

Components Location



1. Fuel Tank
2. Fuel Pump (Including full pressure regulator and fuel filter)
3. Fuel Hose Assy
4. Fuel Rail
5. Injector

Fuel Pressure Test

Release The Internal Pressure



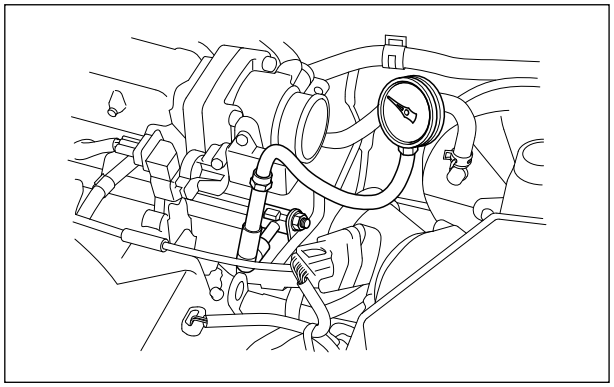
1. Disconnect the fuel pump connector (1).

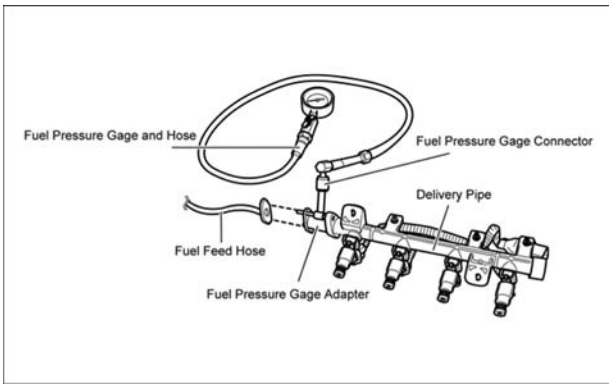
2. Start the engine and wait until fuel in fuel line is exhausted.

3. After the engine stalls, turn the ignition switch to OFF position and diconnect the negative (-) terminal from the battery.

NOTE: Be sure to reduce the fuel pressure before disconnecting the fuel feed hose, otherwise fuel will spill out.

Install Service Tool For Measuring The Fuel Pressure





1. Disconnect the fuel feed hose from the delivery pipe.

⚠ CAUTION

Cover the hose connection with a shop towel to prevent splashing of fuel caused by residual pressure in the fuel line.

2. Install the Fuel Pressure Gage Adapter between the delivery pipe and the fuel feed hose.

3. Connect the Fuel Pressure Gage Connector to the Fuel Pressure Gage Adapter.

4. Connect the Fuel Pressure Gage and Hose to Fuel Pressure Gage Connector.

5. Connect the fuel feed hose to the Fuel Pressure Gage Adapter.

Inspect Fuel Leakage On Connection

1. Connect the battery negative (-) terminal.

2. Apply battery voltage to the fuel pump terminal and activate the fuel pump. With fuel pressure applied, check that there is no fuel leakage from the fuel pressure gauge or connection part.

Fuel Pressure Test

1. Diconnect the negative (-) terminal from the battery.

2. Connect the fuel pump connector.

3. Connect the battery negative (-) terminal.

4. Start the engine and measure the fuel pressure at idle.

Standard Value: 350 kPa (3.5 kg/, 49.8 psi)

• If the measured fuel pressure differs from the standard value, perform the necessary repairs

Condition	Probable Cause	Supected Area
Fuel Pressure too low	Clogged fuel filter	Fuel filter
	Fuel leak on the fuel-pressure regulator that is assembled on fuel pump because of poor seating of the fuel-pressure regulator.	Fuel Pressure Regulator
Fuel Pressure too High	Sticking fuel pressure regulator	Fuel Pressure Regulator

5. Stop the engine and check for a change in the fuel pressure gauge reading.

After engine stops, the gage reading should hold for about 5 minutes

• Observing the declination of the fuel pressure when the gage reading drops and perform the necessary repairs using the table below.

Condition	Probable Cause	Supected Area
Fuel pressure drops slowly after engine is stopped	Injector leak	Injector
Fuel pressure drops immediately after engine is stopped	The check valve within the fuel pump is open	Fuel Pump

Release The Internal Pressure



1. Disconnect the fuel pump connector (1).

2. Start the engine and wait until fuel in fuel line is exhausted.

3. After the engine stalls, turn the ignition switch to OFF position and diconnect the negative (-) terminal from the battery.

NOTE: Be sure to reduce the fuel pressure before disconnecting the fuel feed hose, otherwise fuel will spill out.

Remove Service Tool And Connect the Fuel Line

1. Disconnect the Fuel Pressure Gage and Hose from the Fuel Pressure Gage Connector.

2. Disconnect the Fuel Pressure Gage Connector from the Fuel Pressure Gage Adapter.

3. Disconnect the fuel feed hose from the Fuel Pressure Gage Adapter.

4. Disconnect the Fuel Pressure Gage Adapter from the delivery pipe.

⚠ CAUTION

Cover the hose connection with a shop towel to prevent splashing of fuel caused by residual pressure in the fuel line.

5. Conenct the fuel feed hose to the delivery pipe.

Inspect Fuel Leakage On Connection

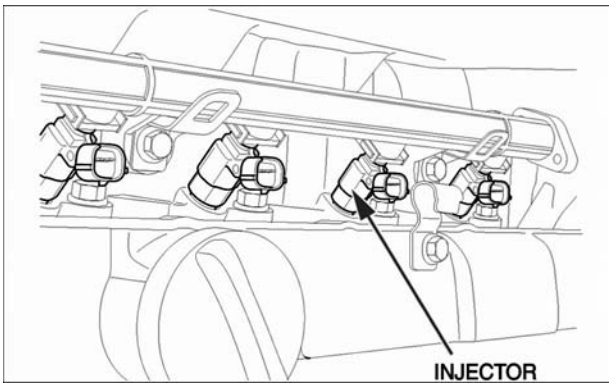
1. Connect the battery negative (-) terminal.

2. Apply battery voltage to the fuel pump terminal and activate the fuel pump. With fuel pressure applied, check that there is no fuel leakage from the fuel pressure gauge or connection part.

3. If the vehicle is normal, connect the fuel pump connector.

Injector

Component Location



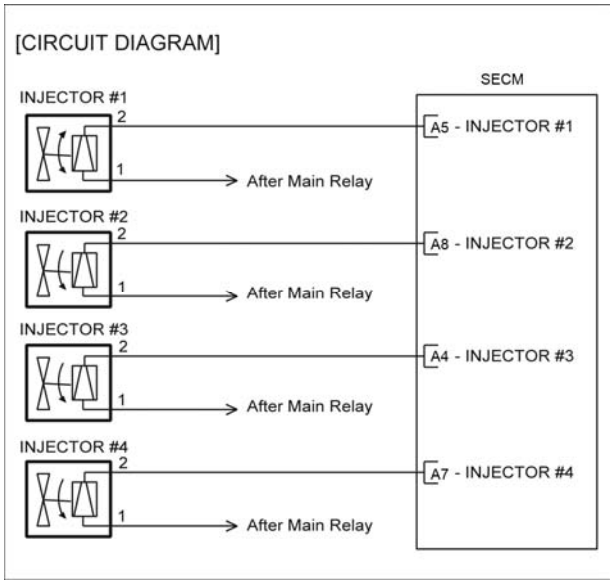
Description

Based on information from various sensors, the ECM measures the fuel injection amount. The fuel injector is a solenoid-operated valve and the fuel injection amount is controlled by length of time the fuel injector is held open. The ECM controls each injector by grounding the control circuit. When the ECM energizes the injector by grounding the control circuit, the circuit voltage should be low (theoretically 0V) and the fuel is injected. When the ECM de-energizes the injector by opening control circuit, the fuel injector is closed and circuit voltage should be peak for a moment.

Specification

Injector resistane : 12~14Ω

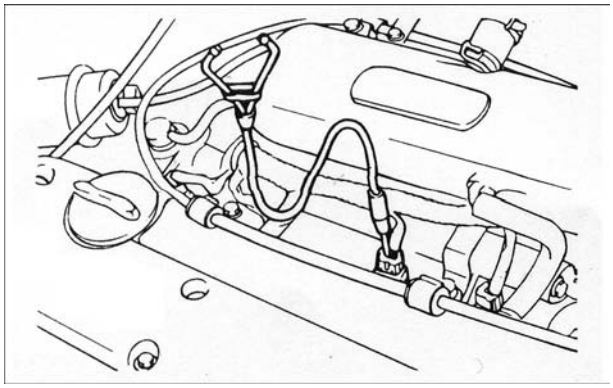
Schematic diagram



Injector Inspection

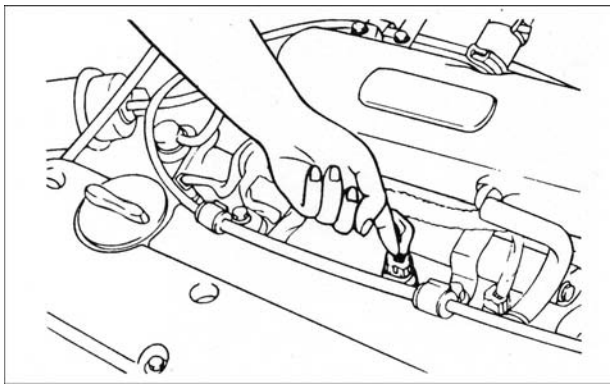
Operation check

Operation Sound Check



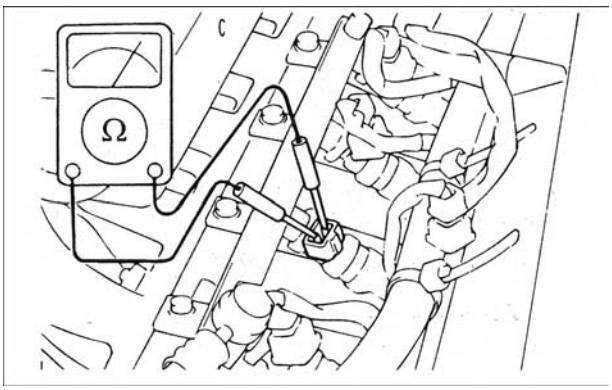
1. Using a stethoscope, check the injectors for a clicking sound at idle. Check that the sound is produced at shorter intervals as the engine speed increases.

NOTE: Ensure that the sound from an adjacent injector is not being transmitted along the delivery pipe to an inoperative injector.



2. If a stethoscope is not available, check the injector operation with your finger. If no vibrations are felt, check the wiring connector, injector, or injection signal from ECM.

Resistance Measurement Between Terminals



1. Disconnect the connector at the injector and measure the resistance between the two terminals.

Standard value : 12-14Ω [at 20℃ (68°F)]

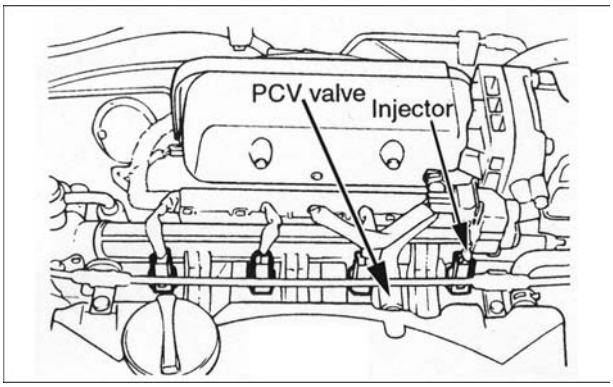
2. Re-connect the connector to the injector.

Removal

1. Release residual pressure from the fuel line to prevent fuel from spilling.

⚠ CAUTION

Cover the hose connection with rags to prevent splashing of fuel that could be caused by residual pressure in the fuel line.



2. Remove the delivery pipe with the fuel injectors.

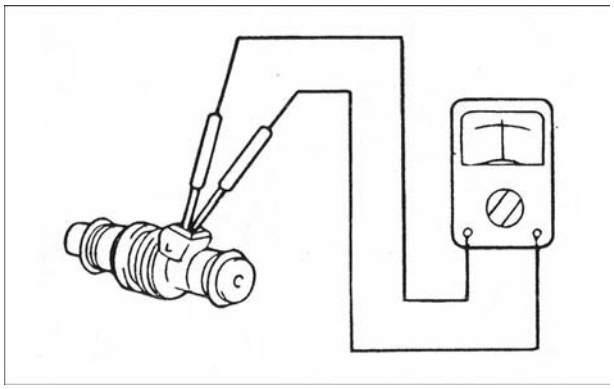
⚠ CAUTION

Be careful not to drop any injectors when removing the delivery pipe.
Be aware that fuel may flow out when removing the injector.

Inspection

1. Measure the resistance of the injectors between the terminals using an ohmmeter.

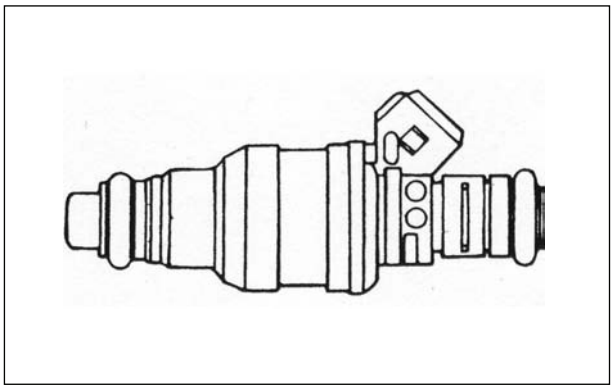
Resistance : 12-14Ω [at 20℃ (68°F)]



2. If the resistance is not within specifications, replace the injector.

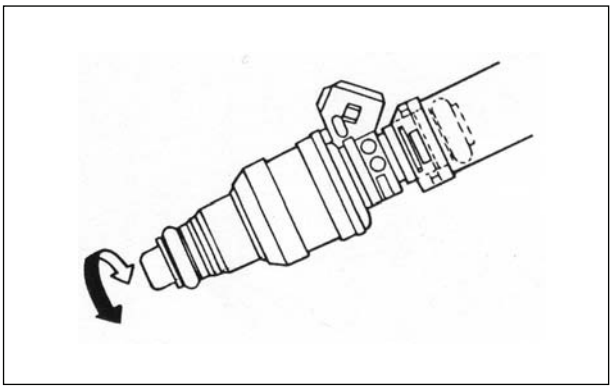
Installation

1. Install a new grommet and O-ring to the injector.



2. Apply a coating of solvent, spindle oil or gasoline to the O-ring of the injector.

3. While turning the injector to the left and right, fit it on to the delivery pipe.

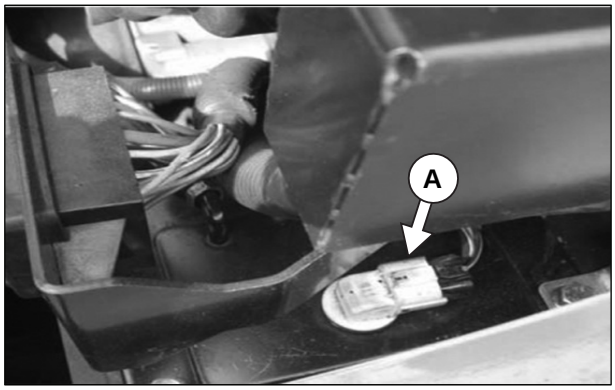


4. Be sure the injector turns smoothly.

NOTE: If it does turn smoothly, the O-ring may be jammed : Remove the injector and re-insert it into the delivery pipe and recheck.

Fuel Pump

Removal (Including Fuel Filter And Fuel Pressure Regulator)



1. Release the internal pressure of the fuel lines and hoses as following :

a. Disconnect the fuel pump assembly harness connector (A).

b. Start the engine and wait until fuel in fuel line is exhausted. After the engine stalls, turn the ignition switch to OFF position.

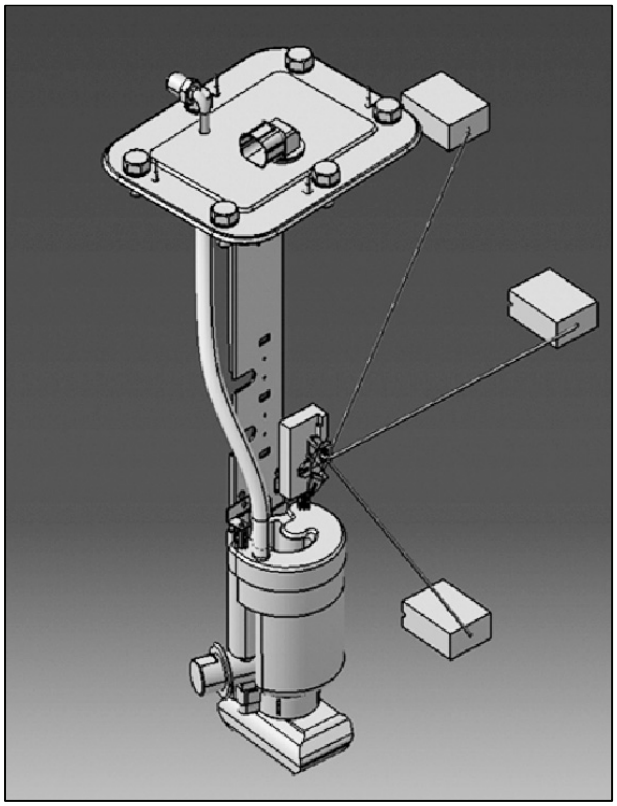
c. Disconnect the negative (-) terminal from the battery.

2. Disconnect the fuel feed line.

⚠ CAUTION

Cover the hose connection with a shop towel to prevent splashing of fuel caused by residual pressure in the fuel line.

3. Unfasten the fuel pump cap (D) counter clock wise.



4. Remove the fuel pump assembly.

Chapter 8. BASIC TROUBLESHOOTING

Preliminary Checks

MI-07 systems are equipped with built-in fault diagnostics. Detected system faults can be displayed by the Malfunction Indicator Lamp (MIL) and are covered in Chapter 9, Advanced Diagnostics. However, items such as fuel level, plugged fuel lines, clogged fuel filters, and malfunctioning pressure regulators may not set a fault code and usually can be corrected with the basic troubleshooting steps described on the following pages.

If engine or drivability problems are encountered with your MI-07 system, perform the checks in this section before referring to Advanced Diagnostics.

NOTE: Locating a problem in a propane engine is done exactly the same as with a gasoline engine. Consider all parts of the ignition and mechanical systems as well as the fuel system.

Before Starting

1. Determine that the SECM and MIL light are operating. Verify operation by keying on engine and checking for flash of MIL light. When the ignition key is turned on, the MIL will illuminate and remain on until the engine is started. Once the engine is started, the MIL lamp will go out unless one or more fault conditions are present. If a detected fault condition exists, the fault or faults will be stored in the memory of the small engine control module (SECM). Once an active fault occurs the MIL will illuminate and remain ON. This signals the operator that a fault has been detected by the SECM.

2. Determine that there are no diagnostic codes stored, or there is a diagnostic code but no MIL light.

Visual/Physical check

Several of the procedures call for a “Careful Visual/Physical Check” which should include:

- SECM grounds for being clean and tight
- Vacuum hoses for splits, kinks, and proper connection.
- Air leaks at throttle body mounting and intake manifold
- Exhaust system leaks
- Ignition wires for cracking, hardness, proper routing, and carbon tracking
- Wiring for pinches and cuts

Also check:

- Connections to determine that none are loose, cracked, or missing
- Fuel level in vehicle is sufficient
- Fuel is not leaking
- Battery voltage is greater than 11.5 volts
- Steering, brakes, and hydraulics are in proper condition and vehicle is safe to operate

NOTE: The Visual/Physical check is very important, as it can often correct a problem without further troubleshooting and save valuable time.

Basic Troubleshooting Guide

Customer Problem Analysis Sheet

1. Forklift Information

(I) VIN:
(II) ProductionDate:
(III) Hour meter Reading: (hrs)

2. Symptoms

☐ Unable to start	☐ Engine does not turn over ☐Incomplete combustion ☐ Initial combustion does not occur
☐ Difficult to start	☐ Engine turns over slowly ☐ Other_____
☐ Poor idling	☐ Rough idling ☐ Incorrect idling ☐Unstable idling (High: _____ rpm, Low: _____ rpm) ☐ Other_____
☐ Engine stall	☐ Soon after starting ☐ After accelerator pedal depressed ☐After accelerator pedal released ☐ Shifting from N to D-range ☐ Other_____
☐ Others	☐ Poor driving (Surge) ☐ Knocking ☐ Poor fuel economy ☐ Back fire ☐ After fire ☐ Other_____

3. Environment

Problem frequency	☐ Constant ☐ Sometimes (_____) ☐ Once only ☐ Other_____
Weather	☐ Fine ☐ Cloudy ☐ Rainy ☐ Snowy ☐ Other_____
Outdoor temperature	Approx._____ ℃/℉
Place	☐ Suburbs ☐ Inner City ☐ Uphill ☐ Downhill ☐ Rough road ☐ Other_____
Engine temperature	☐ Cold ☐ Warming up ☐ After warming up ☐ Any temperature
Engine operation	☐ Starting ☐ Just after starting (____min) ☐ Idling ☐ Racing ☐ Driving ☐ Constant speed ☐ Acceleration ☐ Deceleration ☐ Other_____

4. MIL/DTC

MIL (Malfunction Indicator Lamp)	☐ Remains ON ☐ Sometimes lights up ☐ Does not light
DTC	☐ Normal ☐ DTC(_____)

Basic Inspection Procedure

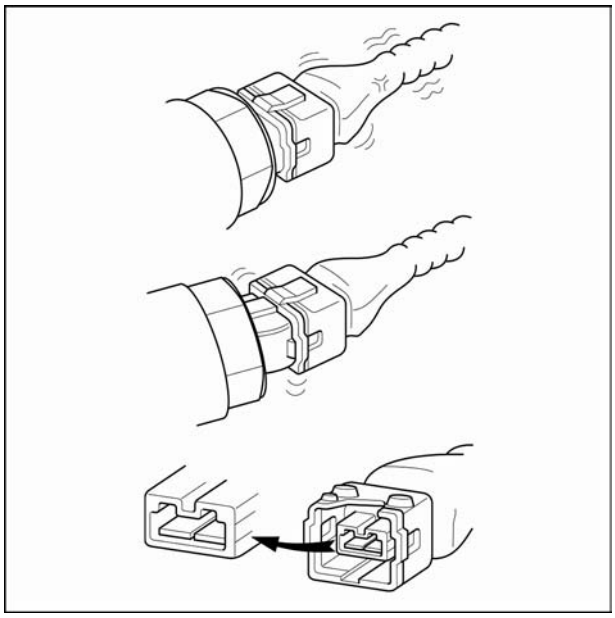
Measuring Condition Of Electronic Parts Resistance

The measured resistance at high temperature after vehicle running may be high or low. So all resistance must be measured at ambient temperature (20℃, 68 ℉), unless there is any notice.

NOTE: The measured resistance in except for ambient temperature (20℃, 68℉) is reference value.

Intermittent Problem Inspection Procedure

Sometimes the most difficult case in troubleshooting is when a problem symptom occurs but does not occur again during testing. An example would be if a problem appears only when the vehicle is cold but has not appeared when warm. In this case, technician should thoroughly make out a "CUSTOMER PROBLEM ANALYSIS SHEET" and recreate (simulate) the environment and condition which occurred when the vehicle was having the issue.



1. Clear Diagnostic Trouble Code (DTC).

2. Inspect connector connection, and check terminal for poor connections, loose wires, bent, broken or corroded pins, and then verify that the connectors are always securely fastened.

3. Slightly shake the connector and wiring harness vertically and horizontally.

4. Repair or replace the component that has a problem.

5. Verify that the problem has disappeared with the road test.

● SIMULATING VIBRATION

1) Sensors and Actuators
: Slightly vibrate sensors, actuators or relays with finger.

⚠ WARNING

Strong vibration may break sensors, actuators or relays.

2) Connectors and Harness
: Lightly shake the connector and wiring harness vertically and then horizontally.

● Simulating Heat

1) Heat components suspected of causing the malfunction with a hair dryer or other heat sourre.

⚠ WARNING

DO NOT heat components to the point where they may be damaged.
DO NOT heat the ECM directly.

● Simulating Water Sprinkling

1) Sprinkle water onto vehicle to simulate a rainy day or a high humidity condition.

⚠ WARNING

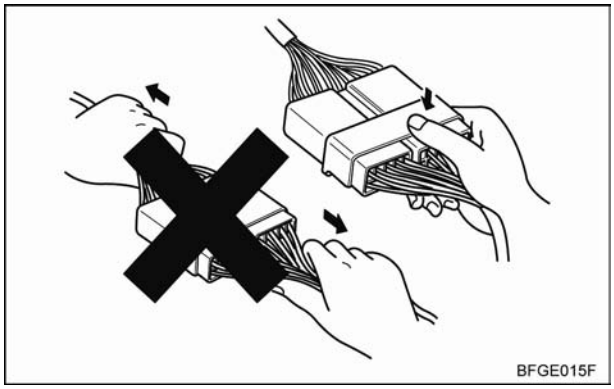
DO NOT sprinkle water directly into the engine compartment or electronic components.

● Simulatingelectricalload

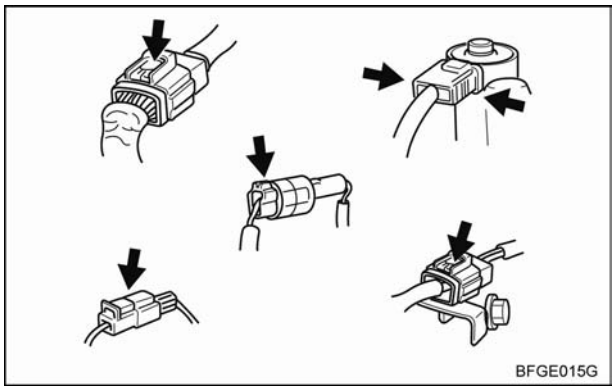
1) Turn on all electrical systems to simulate excessive electrical loads (Radios, fans, lights, etc.).

Connector Inspection Procedure

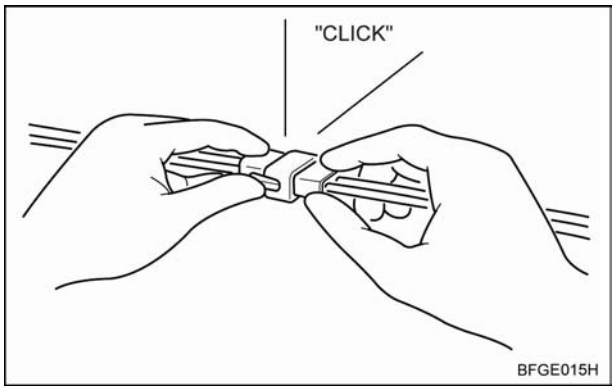
Handling of Connector



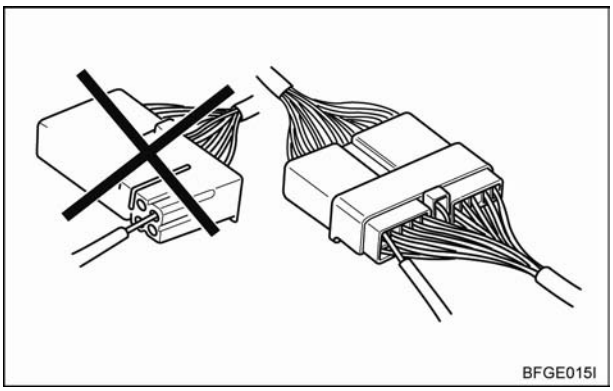
1. Never pull on the wiring harness when disconnecting connectors.



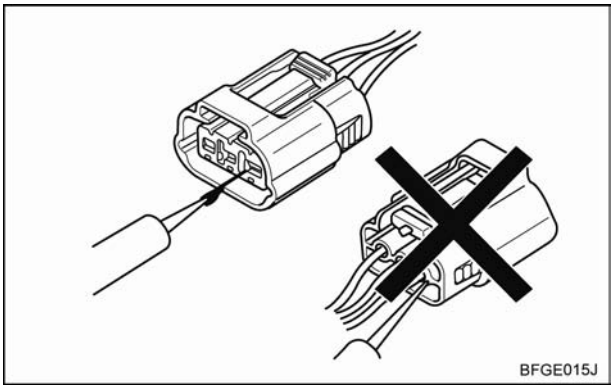
2. When removing the connector with a lock, press or pull locking lever.



3. Listen for a click when locking connectors. This sound indicates that they are securely locked.



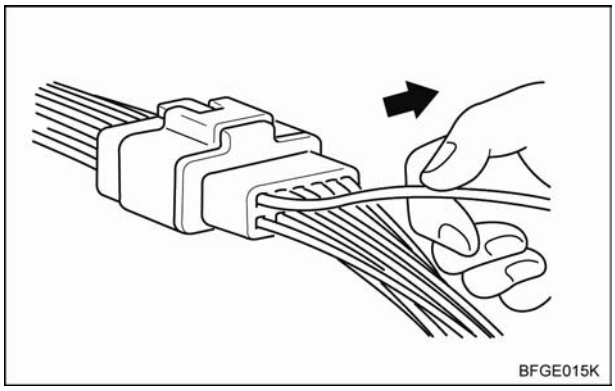
4. When a tester is used to check for continuity, or to measure voltage, always insert tester probe from wire harness side.



5. Check waterproof connector terminals from the connector side. Waterproof connectors cannot be accessed from harness side.

NOTE: Use a fine wire to prevent damage to the terminal. Do not damage the terminal when inserting the tater lead.

Checking Point for Connector



1. While the connector is connected:
Hold the connector, check connecting condition and locking efficiency.

2. When the connector is disconnected:
Check missed terminal, crimped terminal or broken core wire by slightly pulling the wire harness. Visually check for rust, contamination, deformation and bend.

3. Check terminal tightening condition:
Insert a spare male terminal into a female terminal and then check terminal tightening conditions.

4. Pull lightly on individual wires to ensure that each wire is secured in the terminal.

Repair Method of Connector Terminal

1. Clean the contact points using air gun and/or shop rag.

NOTE: Never uses and paper when polishing the contact points, otherwise the contact point may be damaged.

2. In case of abnormal contact pressure, replace the female terminal.

Wire Harness Inspection Procedure

1. Before removing the wire harness, check the wire harness position and crimping in order to restore it correctly.

2. Check whether the wire harness is twisted, pulled or loosened.

3. Check whether the temperature of the wire harness is abnormally high.

4. Check whether the wire harness is rotating, moving or vibrating against the sharp edge of a part.

5. Check the connection between the wire harness and any installed part.

6. If the covering of wire harness is damaged; secure, repair or replace the harness.

Electrical Circuit Inspection Procedure

● Check Open Circuit

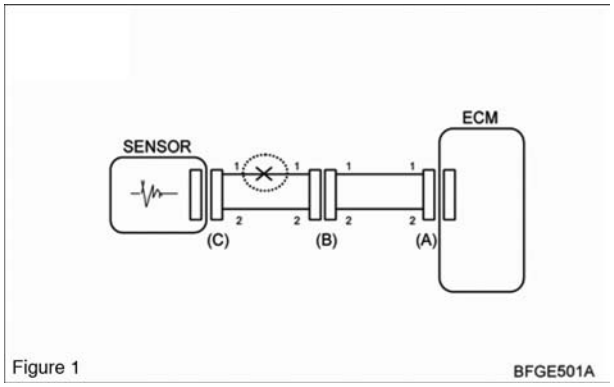


Figure 1 BFGE501A

1. Procedures for Open Circuit

• Continuity Check

• Voltage Check

If an open circuit occurs (as seen in [FIG.1]), it can be found by performing Step 2 (Continuity Check) or Step 3 (Voltage Check Method) as shown below.

2. Continuity Check Method

NOTE: When measuring for resistance, lightly shake the wire harness above and below or from side to side.

Specification (Resistance)
1Ω or less → Normal Circuit
1MΩ or Higher → Open Circuit

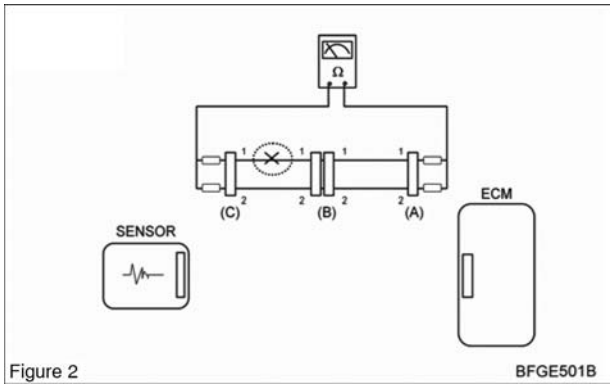


Figure 2 BFGE501B

a. Disconnect connectors (A), (C) and measure resistance between connector (A) and (C) as shown in [FIG.2].

In [FIG.2.] the measured resistance of line1and 2 is higher than 1MΩ and below 1Ω respectively. Specifically the open circuit is line 1(Line 2 is normal). To find exact break point, check sub line of line 1as described in next step.

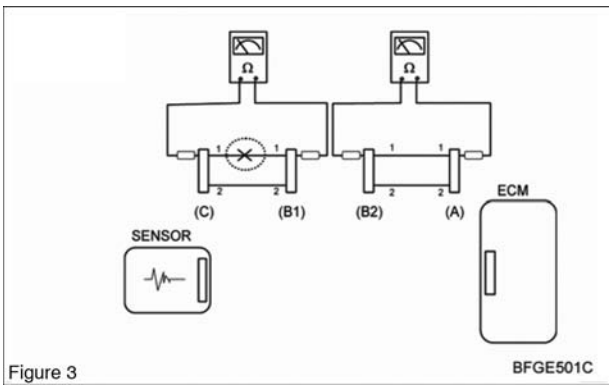


Figure 3 BFGE501C

b. Disconnect connector (B), and measure for resis tance between connector (C) and (B1) and between (B2) and (A) as shown in [FIG.3]. In this case the measured resistance between connector (C) and (B1) is higher than 1MΩ and the open circuit is between terminal 1 of connector (C) and terminal 1 of connector (B1).

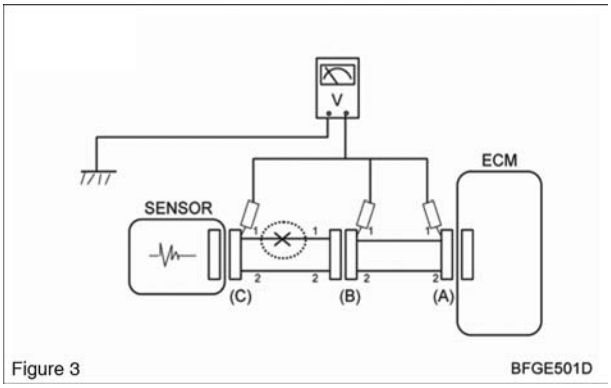


Figure 3 BFGE501D

3. Voltage Check Method

a. With each connector still connected, measure the voltage between the chassis ground and terminal1 of each connectors (A), (B) and (C) as shown in [FIG.4].

The measured voltage of each connector is 5V, 5V and 0V respectively. So the open circuit is between connector (C) and (B).

● Check Short Circuit

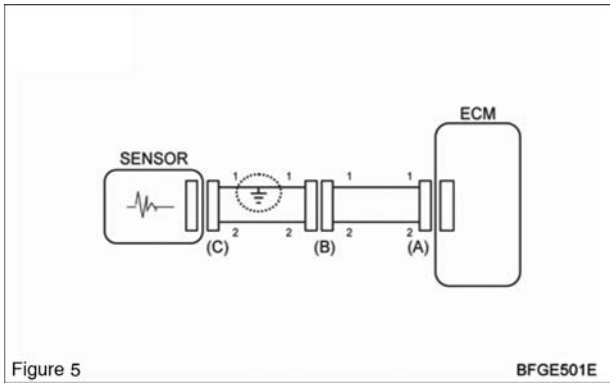


Figure 5 BFGE501E

1. Test Method for Short to Ground Circuit

• Continuity Check with Chassis Ground

If short to ground circuit occurs as shown in [FIG.5], the broken point can be found by performing below Step 2 (Continuity Check Method with Chassis Ground) as shown below.

2. Continuity Check Method (with Chassis Ground)

NOTE: Lightly shake the wire harness above and below, or from side to side when measuring the resistance.

Specification (Resistance)
1Ω or less → Short to Ground Circuit
1MΩ or Higher → Normal Circuit

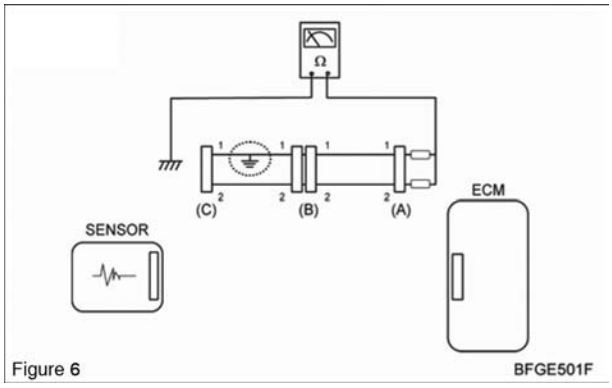


Figure 6 BFGE501F

a. Disconnect connectors (A), (C) and measure for resistance between connector (A) and Chassis Ground as shown in [FIG.6].

The measured resistance of line 1 and 2 in this example is below 1Ω and higher than 1MΩ respectively. Specifically the short to ground circuit is line 1 (Line 2is normal). To find exact broken point, check the sub line of line1 as described in the following step.

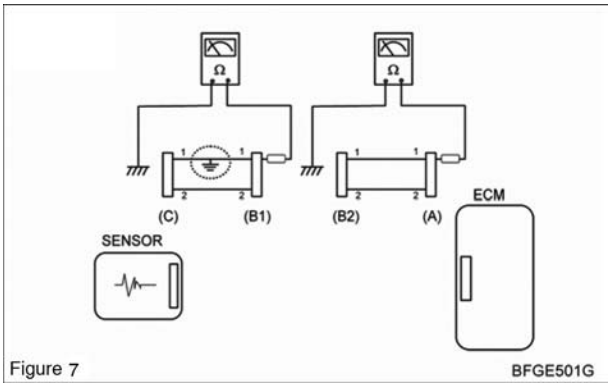


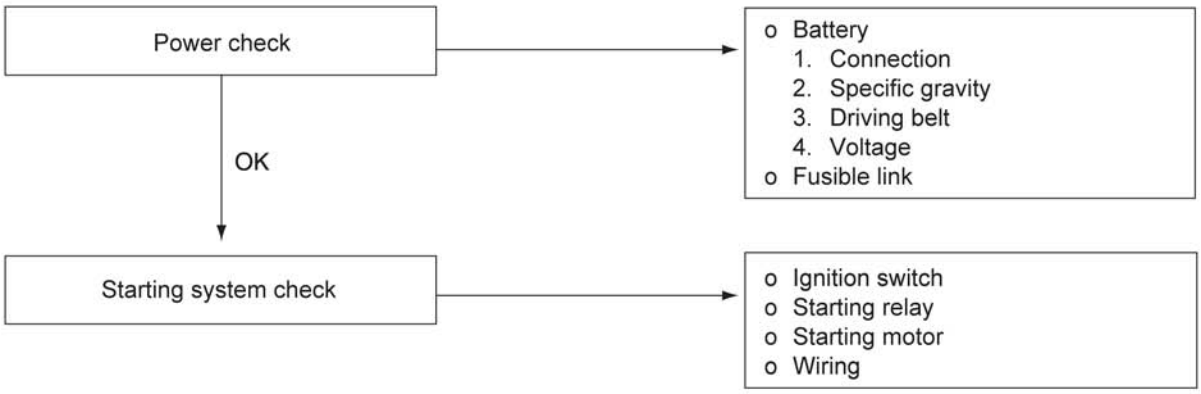
Figure 7 BFGE501G

b. Disconnect connector (B), and measure the resistance between connector (A) and chassis ground, and between (B1) and chassis ground as shown in [FIG.7].

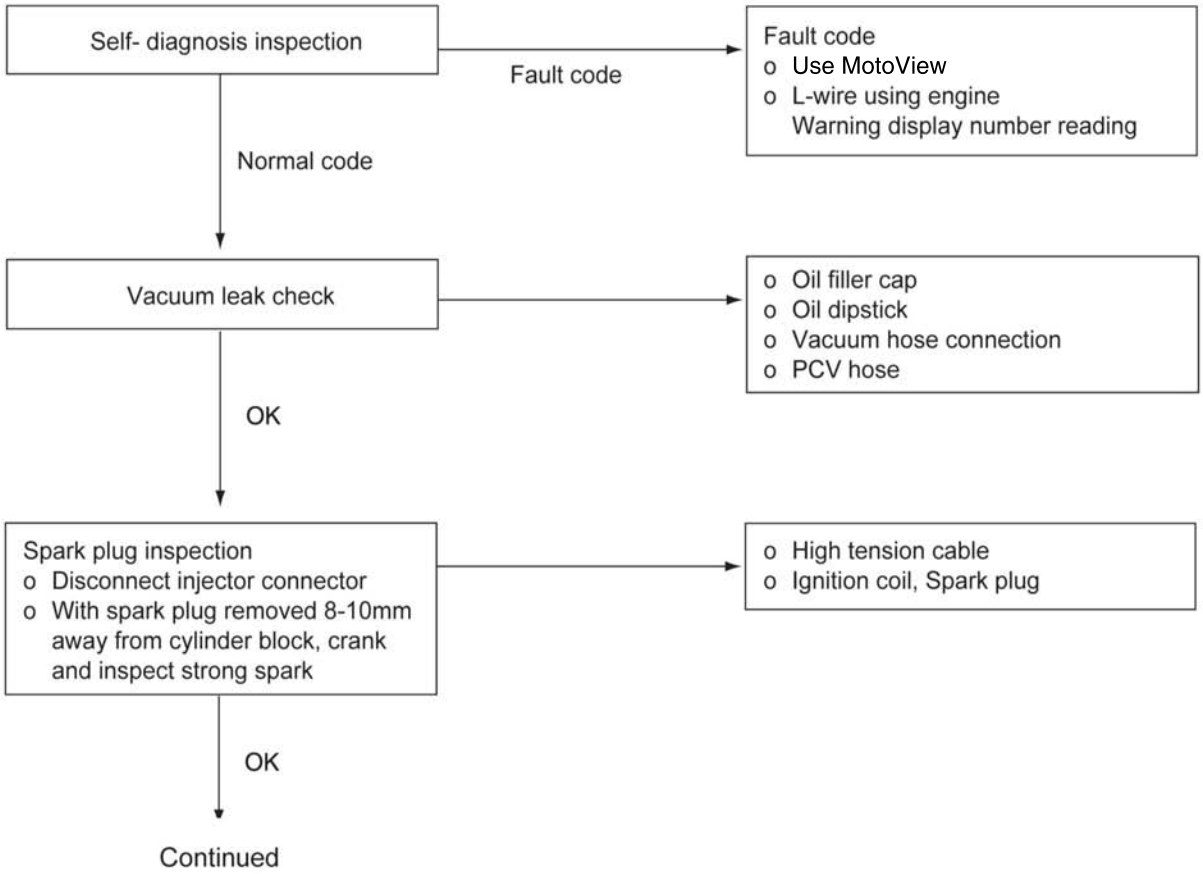
The measured resistance between connector (B1) and chassis groundis1Ω or less. The short to ground circuit is between terminal 1 of connector (C) and terminal 1 of connector (B1).

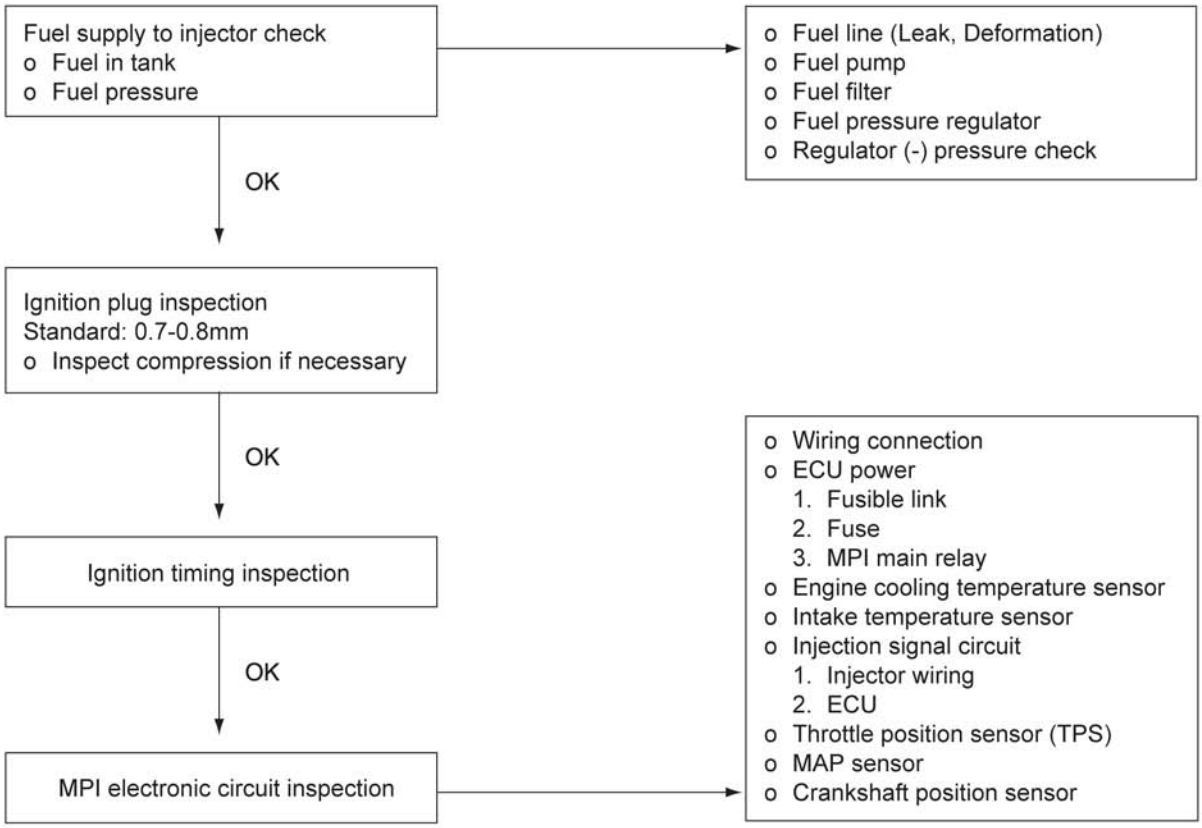
Symptom Troubleshooting Guide Chart for MPI Gasoline System

Engine Is Not Starting

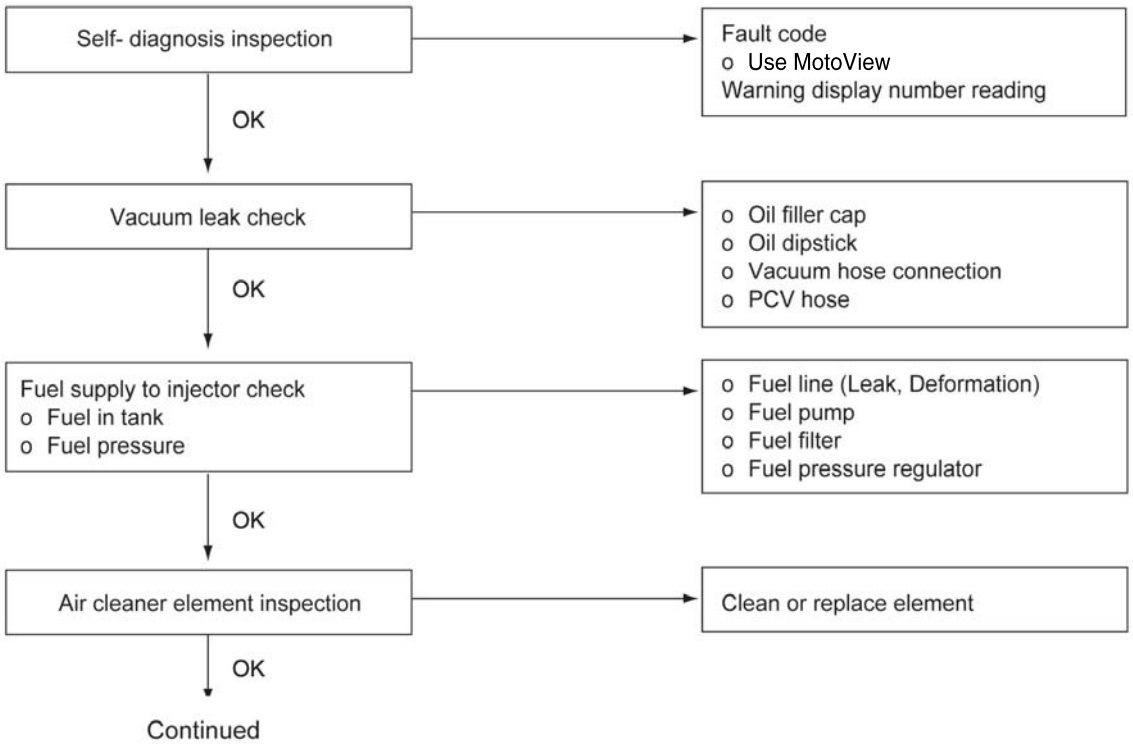


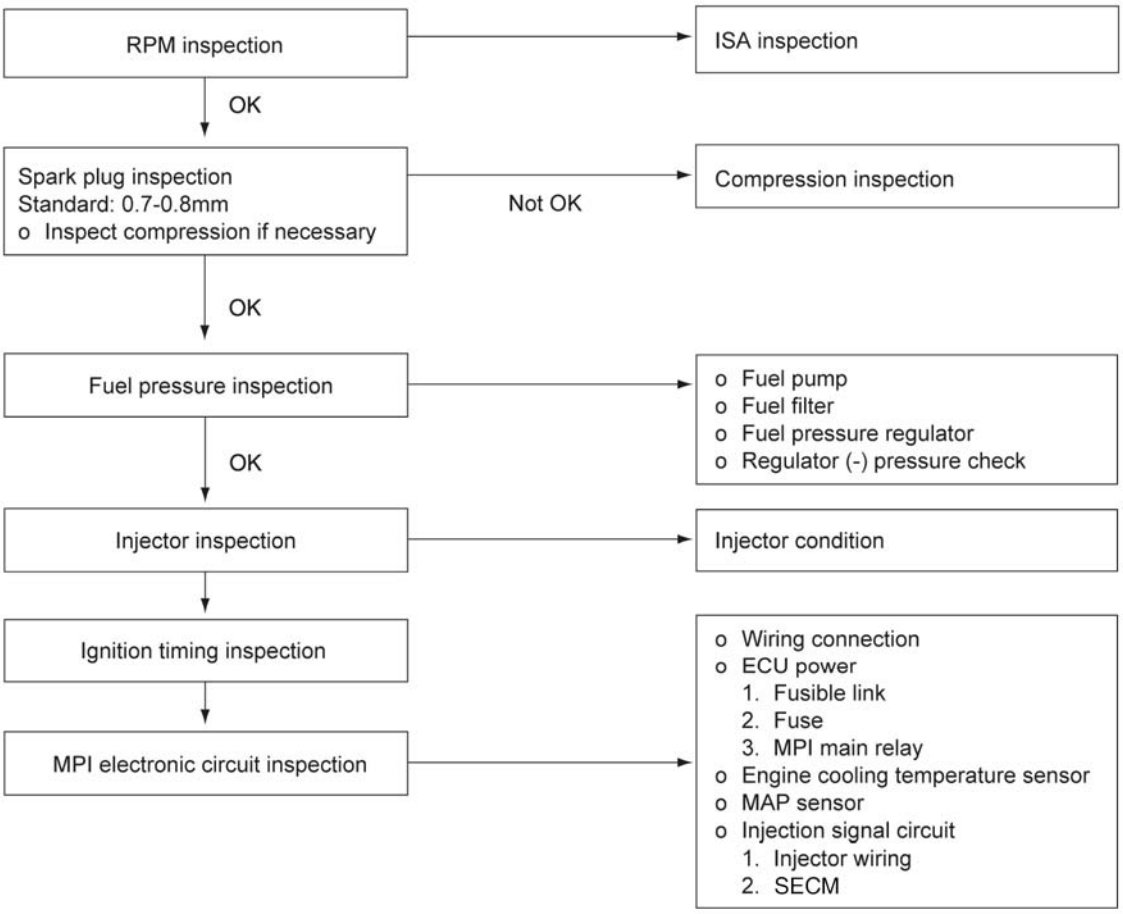
Engine Is Difficult To Start (Cranking OK)



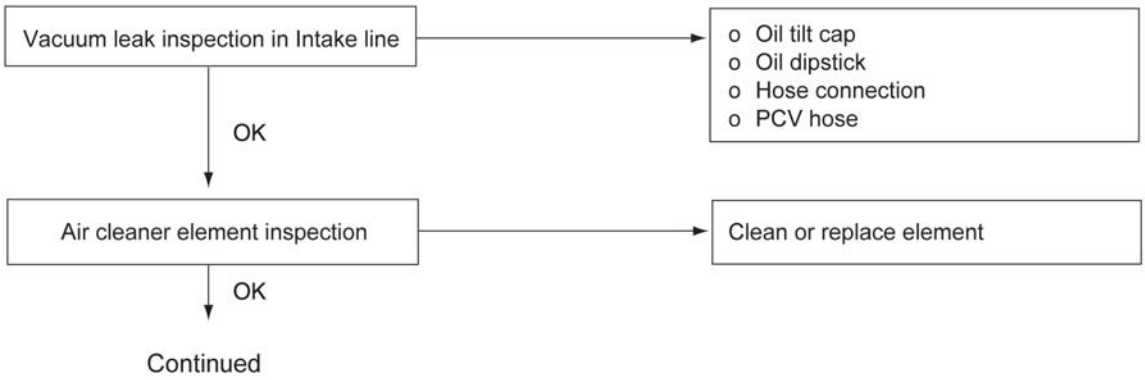


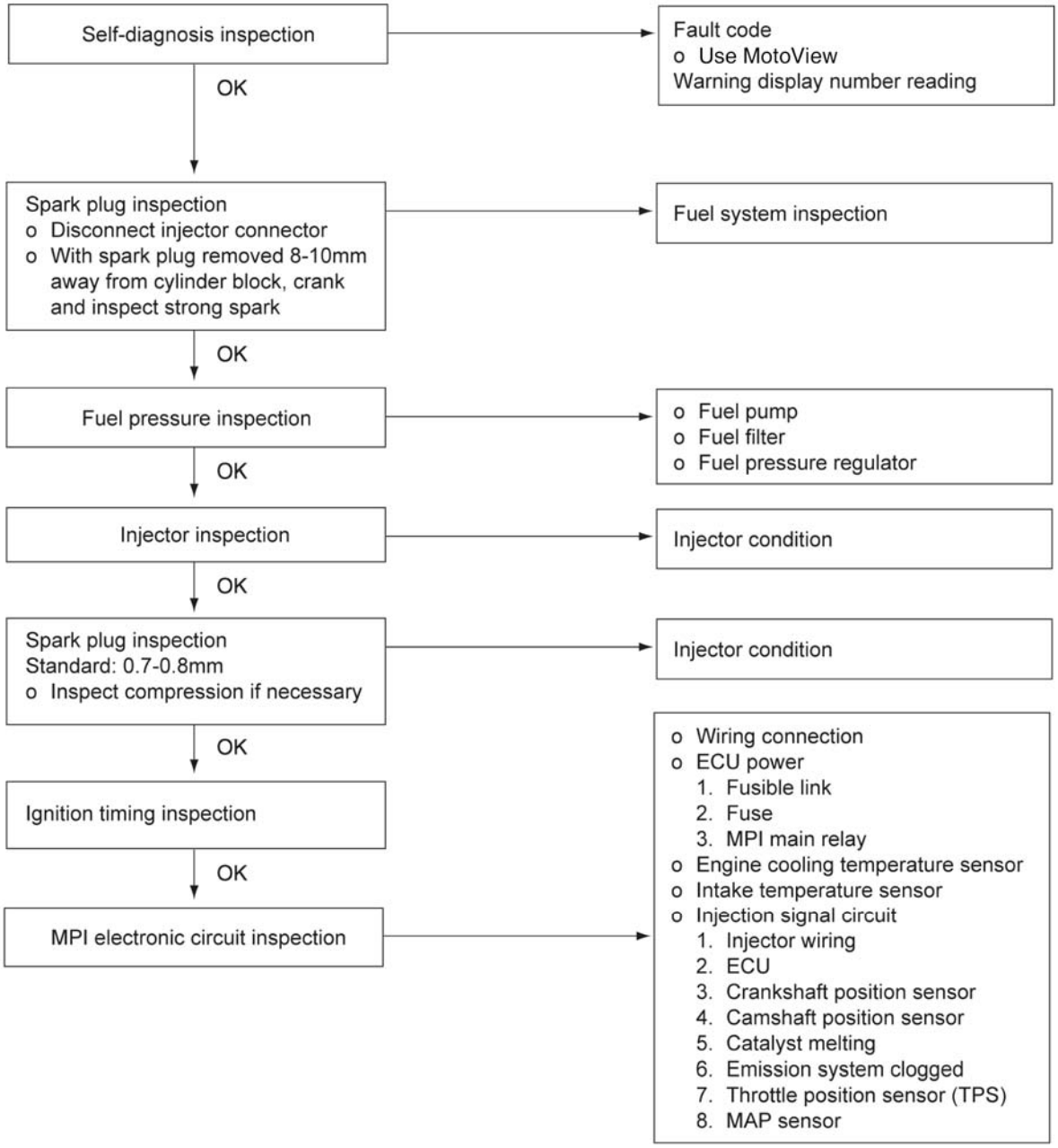
Irregular Idling Or Engine Is Suddenly Stopped





Engine Hesitation Or Insuffient Accelelation




Self-diagnosis inspection
OK
Fault code
o Use MotoView
Warning display number reading
Spark plug inspection
o Disconnect injector connector
o With spark plug removed 8-10mm away from cylinder block, crank and inspect strong spark
Fuel system inspection
OK
Fuel pressure inspection
o Fuel pump
o Fuel filter
o Fuel pressure regulator
OK
Injector inspection
Injector condition
OK
Spark plug inspection
Standard: 0.7-0.8mm
o Inspect compression if necessary
Injector condition
OK
Ignition timing inspection
OK
MPI electronic circuit inspection
o Wiring connection
o ECU power
1. Fusible link
2. Fuse
3. MPI main relay
o Engine cooling temperature sensor
o Intake temperature sensor
o Injection signal circuit
1. Injector wiring
2. ECU
3. Crankshaft position sensor
4. Camshaft position sensor
5. Catalyst melting
6. Emission system clogged
7. Throttle position sensor (TPS)
8. MAP sensor

Troubleshooting Guide for MPI Gasoline System

• The following number represents inspection order.

Main symptom	Item / Sub symptom	Starter relay	Starter	Flywheel	TMAP sensor circuit	Fuel pressure regulator	Water temperature sensor	Compression	Piston ring	Ignition timing	Timing belt	Injector	SECM	A/C circuit	Connecting rod bearing	Fuel chamber	Crankshaft bearing
Starting	Not cranking	1	2														
	Starter is rotating but not cranking		1	2													
	Incomplete combustion				1	2	3	4	5	6	7	8	9				
	Increasingly cranking		1											2	3	4	
	Normally difficult to start					4	3	7	8	9		12	13				1
	Difficult to start when cold					4	1					7	8				2
	Difficult to start when hot					4	1					7	8				2
Faulty idling	Incorrect initial idling						1					4	5	3			
	Low RPM				2		1					3	4				
	Irregular idling				9	4		7	8	10	11	12	14				1
	Engine hesitation or deceleration				4	8	5	3		11		12	13				1
Engine stops	After starting, engine stops soon				5	2	6					7	8				1
	After depressing acceleration pedal, engine stops				1	3						5	6				
	After releasing acceleration pedal, engine stops				1								2				
	With A/C ON, engine stops												2	1			
Other	Fuel over-consumption				11		10	6	7	8		9	14	12		1	5

	Item / Sub symptom	Crankshaft position sensor	Spark plug	Fuel pump	Fuel line	Ignition circuit	Intake temperature sensor circuit	Cylinder head	Oxygen sensor circuit	Fuel leak
Starting	Not cranking									
	Starter is rotating but not cranking	3								
	Incomplete combustion									
	Increasingly cranking									
	Normally difficult to start		2	5	6	10	11			
	Difficult to start when cold			5	6		3			
	Difficult to start when hot			5	6		3			
Faulty idling	Incorrect initial idling						2			
	Low RPM									
	Irregular idling		3	5	6	13	2	15		
	Engine hesitation or deceleration		2	9	10		6		7	
Engine stops	After starting, engine stops soon			3	4					
	After depressing acceleration pedal, engine stops		2		4					
	After releasing acceleration pedal, engine stops									
	With A/C ON, engine stops									
Other	Fuel over-consumption		4			13	2	3		

Main symptom	Item / Sub symptom	Coolant leak	Cooling fan	Radiator and radiator cap	Thermostat	Timing belt	Water pump	Spark plug	Oil pump	Cylinder head	Cylinder block	Coolant temperature gauge
Other	Engine is overheated	1	2	4	5	6	7	8	9	10	11	12
	Engine is supercooled		1		2							3

Basic Troubleshooting

Intermittents

An intermittent fault is the most difficult to troubleshoot since the MIL flashes on at random, causing uncertainty in the number of flashes or the conditions present at the time of the fault. Also, the problem may or may not fully turn “ON” the MIL light or store a code.

Therefore, the fault must be present or able to be recreated in order to locate the problem. If a fault is intermittent, use of diagnostic code charts may result in the unnecessary replacement of good components.

Corrective Action

Most intermittent problems are caused by faulty electrical connections or wiring. Perform careful visual/physical check for:

- Poor mating of the connector halves or terminal not fully seated in the connector body (backed out)
- Improperly formed or damaged terminal. All connector terminals in problem circuit should be carefully reformed or replaced to insure proper contact tension
- Loose connections or broken wires
- Poor terminal to wire connection crimp

If a visual/physical check does not find the cause of the problem, perform the following:

(1) Drive the vehicle with a voltmeter or “Service” tool connected to a suspected circuit. Check if circuit is active and signal is reasonable.

(2) Using the “Service” tool, monitor the input signal to the SECM to help detect intermittent conditions.

(3) An abnormal voltage, or “Service” reading, when the problem occurs, indicates the problem may be in that circuit.

(4) If the wiring and connectors check OK, and a diagnostic code was stored for a circuit having a sensor, check sensor.

An intermittent “Service Engine Soon” light with no stored diagnostic code may be caused by:

- Ignition coil shortage to ground and arcing at spark plug wires or plugs
- MIL light wire to ECM shorted to ground
- SECM grounds (refer to SECM wiring diagrams).

Check for improper installation of electrical options such as lights, 2-way radios, accessories, etc.

EST wires should be routed away from spark plug wires, distributor wires, distributor housing, coil and generator. Wires from SECM to ignition should have a good connection.

Surges and/or Stumbles

Engine power varies under steady throttle or cruise. Feels like the vehicle speeds up and slows down with no change in the acceleration pedal.

Preliminary Checks
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Be sure driver understands vehicle operation as explained in the operator manual.

PROBABLE CAUSE	CORRECTIVE ACTION
Oxygen sensor malfunction	The fuel management should maintain a stoichiometric air-fuel ratio under all steady state operating conditions following engine warmup. Failure of the Pre-catalyst O2 sensor should cause an O2 sensor fault that can be diagnosed with the MIL lamp or Service Tool.
Fuel system malfunction	NOTE: To determine if the condition is caused by a rich or lean system, the vehicle should be driven at the speed of the complaint. Monitoring pre-catalyst O2 adapts*, dither valve duty cycle, or mechanical injector pulse width will help identify problem. Check fuel supply while condition exists. Check in-line fuel filter. Replace if dirty or plugged. Check fuel pressure.
Ignition system malfunction	Check for proper ignition voltage output using spark tester. Check spark plugs. • Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. • Repair or replace as necessary. • Check condition of distributor cap, rotor and spark plug wires (where applicable). Check ignition timing. Refer to application manual for specs.
Component malfunction	Check vacuum lines for kinks or leaks. Check alternator output voltage. Repair if less than 9 or more than 16 volts.
Exhaust backpressure	Check condition of exhaust system. Check backpressure before catalyst. It should be less than 3.5 psig (24.13 kPa).

(*) Refer to Table 1 for description of gaseous and liquid O2 adapts.

Related MIL Faults:
Pre-catalyst O2 sensor errors / O2 control errors
Dither valve DC faults / EST faults / ETC faults

Engine Cranking but Will Not Start / Difficult to Start

Engine cranks OK, but does not start for a long time. Does eventually run, or may start but immediately dies.

Preliminary Checks
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Be sure driver is using correct method to start engine as explained in operator's manual. Use "clear flood" mode during cranking by fully depressing the pedal and cranking the engine. If engine does not start, continue troubleshooting.

PROBABLE CAUSE	CORRECTIVE ACTION
CORRECTIVE ACTION	Verify "selected" fuel with Service Tool. Make sure fuel select switch is in proper position.
Fuel container empty	Check for LPG vapor from LPG liquid outlet valve on tank. Fill fuel container. Do not exceed 80% of liquid capacity.
Liquid valve closed	Slowly open liquid valve.
Propane excess flow valve closed	Reset excess flow valve in LPG tank. Close liquid valve. Wait for a "click" sound; slowly open liquid valve.
Plugged fuel line	Remove obstruction from the fuel line. • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve. • Leak test.
Clogged fuel filter	Repair/replace as required. See Chapter 2 Fuel Filter replacement.
Faulty vapor connection between the pressure regulator/converter and the mixer	Check connection • Verify no holes in hose. • Clamps must be tight. • Look for kinked, pinched and/or collapsed hose.
Fuel lock-off malfunction	Repair/replace fuel lock-off. See Chapter 5 Fuel Lock-off.
Pressure regulator/converter malfunction	Test regulator/converter operation and pressure. See Chapter 6 Tests and Adjustments.
Incorrect air/fuel or ignition/spark control	See Chapter 8 Advanced Diagnostics.
No crankshaft position sensor signal	Verify the crankshaft position signal is present See Chapter 8 Advanced Diagnostics.

Engine Cranking but Will Not Start / Difficult to Start (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
SECM / control system malfunction	Check Coolant Temperature Sensor using the Service Tool; compare coolant temperature with ambient temperature on cold engine. If coolant temperature reading is 5° greater than or less than ambient air temperature on a cold engine, check resistance in coolant sensor circuit or sensor itself. Compare CTS resistance value to "Diagnostic Aids" chart at end of this section. Verify that there is no code for ETC spring check fault. Check for 0% APP during cranking. Cycle key ON and OFF and listen for throttle check (movement) on key OFF. Check for oil pressure switch faults. Check for sensor "sticking" faults. Check TPS for stuck binding or a high TPS voltage with the throttle closed.
Fuel system malfunction	Check fuel lock off (propane) or fuel pump relay gasoline operation: actuator should turn "ON" for 2 seconds when ignition is turned "ON". Check fuel pressure. Check for contaminated fuel. Check both gasoline injector and lock off fuses (visually inspect). Check propane tank valve & pickup. A faulty in-tank fuel pump check valve will allow the fuel in the lines to drain back to the tank after engine is stopped. To check for this condition, perform fuel system diagnosis. Check FTV system for proper operation.
Ignition system malfunction	Check for proper ignition voltage output with spark tester. Check spark plugs. Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. Repair or replace as necessary. Check for: • Bare or shorted wires • Loose ignition coil ground • Pickup coil resistance and connections

Related MIL Faults:
ETC spring check / ETC faults / EST faults / TPS conflict
APP faults / Encoder error / MAP faults
Injector faults / Oil pressure faults

Lack of Power, Slow to Respond / Poor High Speed Performance / Hesitation During Acceleration

Engine delivers less than expected power. Little or no increase in speed when accelerator pedal is pushed down part way. Momentary lack of response as the accelerator is pushed down. Can occur at all vehicle speeds. Usually most severe when first trying to make vehicle move, as from a stop. May cause engine to stall.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Drive vehicle; verify problem exists. Remove air filter and check for dirt or other means of plugging. Replace if needed.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for restricted fuel filter. Check fuel supply. Check for LPG vapor from LPG liquid outlet valve on tank. Check for contaminated fuel. Check for clogged fuel filter and repair or replace as required. See Chapter 4 Fuel Filter replacement Check for plugged fuel line and remove any obstruction from the fuel line: • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve and leak test. Check for faulty vapor connection between pressure regulator/converter and mixer: • Verify that there are no holes in hose. • Observe that clamps are tight. • Look for kinked, pinched and/or collapsed hose. Monitor pre-catalyst O2 with Service Tool. Check for proper pressure regulator operation. See Chapter 6 Test and Adjustments. Check for proper air/fuel mixer operation.
Ignition system malfunction	Check spark advance for excessive retarded ignition timing. Use Service Tool. Check secondary voltage using an oscilloscope or a spark tester to check for a weak coil. Check spark plug condition. Check poor spark plug primary and secondary wire condition.

Lack of Power, Slow to Respond / Poor High Speed Performance / Hesitation During Acceleration (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
Component malfunction	Check SECM grounds for cleanliness and secure connection. See SECM wiring diagrams. Check alternator output voltage. Repair if less than 9 volts or more than 16 volts. Check for clogged air filter and clean or replace as required. Check exhaust system for possible restriction. Refer to Chart T-1 on later pages. Inspect exhaust system for damaged or collapsed pipes. • Inspect muffler for heat distress or possible internal failure. • Check for possible plugged catalytic converter by comparing exhaust system backpressure on each side at engine. Check backpressure by removing Pre-catalyst O2 sensor and measuring backpressure with a gauge.
Engine mechanical	See Chapter 3 Engine Mechanical System. Check engine valve timing and compression Check engine for correct or worn camshaft.

Related MIL Faults:
EST faults
ETC faults
ETC spring check
TPS faults
APP faults
Encoder error
Delayed Shutdown faults

Detonation / Spark Knock

A mild to severe ping, usually worse under acceleration. The engine makes sharp metallic knocks that change with throttle opening (similar to the sound of hail striking a metal roof).

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for proper fuel level: • Check for LPG vapor from LPG liquid outlet valve on tank. • Fill fuel container. Do not exceed 80% of liquid capacity. Check fuel pressure. To determine if the condition is caused by a rich or lean system, the vehicle should be driven at the speed of the complaint. Monitoring with the Service tool will help identify problem.
Cooling system malfunction	Check for obvious overheating problems: • Low engine coolant • Loose water pump belt • Restricted air flow to radiator, or restricted water flow through radiator • Inoperative electric cooling fan • Correct coolant solution should be a mix of anti-freeze coolant (or equivalent) and water • High coolant temperature
Ignition system malfunction	Check ignition timing. See application manual. Check spark module wiring.
Exhaust system malfunction	Check exhaust backpressure. Check for debris clogging the catalyst. Check that pre-catalyst O2 sensor is functioning.
Engine mechanical	Check for excessive oil in the combustion chamber and/or blow by from excessive PCV flow. Check combustion chambers for excessive carbon build up. Check combustion chamber pressure by performing a compression test. Check for incorrect basic engine parts such as cam, heads, pistons, etc.

Related MIL Faults:
EST faults
Encoder error
High coolant temperature faults

Backfire

Fuel ignites in intake manifold or in exhaust system, making loud popping noise.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Simulate condition by reviewing operation procedure practiced by vehicle operator.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Perform fuel system diagnosis check: • Check for fuel leaks • Check for MIL faults • Check for damaged components
Ignition system malfunction	Check proper ignition coil output voltage with spark tester. Check spark plugs. Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. Repair or replace as necessary. Check spark plug wires for crossfire; also inspect distributor cap, spark plug wires, and proper routing of plug wires. Check ignition timing. Refer to application manual.
Engine mechanical	Check compression: look for sticking or leaking valves. Check intake and exhaust manifold for casting flash and gasket misalignment. Refer to Chapter 3 Engine Mechanical System.

Related MIL Faults: EST faults / ETC faults / Encoder error
Pre-catalyst O2 sensor faults

Dieseling, Run-on

Engine continues to run after key is turned "OFF," but runs very roughly. If engine runs smoothly, check ignition switch and adjustment.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for fuel leaks or leaking injector.
Ignition switching	Make sure power to system is shut off when key is in OFF position.
Fuel lock off valve	Make sure lock off valve is closing properly.
Ignition system malfunction	Check spark advance at idle.

Related MIL Faults: EST faults / ETC faults / Pre-catalyst O2 sensor faults

Rough, Unstable, Incorrect Idle, or Stalling

Engine cranks OK, but does not start for a long time. Does eventually run, or may start but immediately dies.

PRELIMINARY CHECKS
Perform the visual checks as described at start of “Basic Troubleshooting” chapter. Check for vacuum leaks. Check that SECM grounds are clean and tight. See SECM wiring diagram

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Monitor oxygen feedback to help identify the cause of the problem. If the system is running lean or if the system is running rich evaluate further i.e. dither valve duty cycle and injector pulse width. Check for incorrect minimum idle speed that may be caused by foreign material accumulation in the throttle bore, on the throttle valve, or on the throttle shaft. Check that the injectors are clean and functioning. Check for liquid fuel in propane pressure regulator hose. If fuel is present, replace regulator assembly. The pre-catalyst oxygen (O2) sensor should respond quickly to different throttle positions. If it does not, then check the pre-catalyst O2 sensor for contamination. If the pre-catalyst O2 sensor is aged or contaminated, the SECM will not deliver correct amount of fuel, resulting in a drivability problem.
Fuel container empty	Check for LPG vapor from LPG liquid outlet valve on tank. Fill fuel container. Do not exceed 80% of liquid capacity.
Ignition system malfunction	Check ignition system; wires, plugs, rotor, etc.
LPG pressure regulator malfunction	Test regulator operation and pressure. See Chapter 6 Tests and Adjustments
Air/fuel mixer malfunction	Check mixer.
Component malfunction	Check throttle for sticking or binding. Check PCV valve for proper operation by placing finger over inlet hole in valve end several times. Valve should snap back. If not, replace valve. Check alternator output voltage. Repair if less than 9 or more than 16 volts.
Engine mechanical	Perform a cylinder compression check. See Chapter 3 Engine Mechanical System.

Rough, Unstable, Incorrect Idle, or Stalling (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
Excess flow valve closed	Reset excess flow valve. • Close liquid valve. • Wait for a "click" sound. Slowly open liquid valve.
Clogged fuel filter	Repair/replace as required See Chapter 4 Fuel Filter Replacement
Plugged fuel line	Remove obstruction from the fuel line. • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve & leak test.
Fuel lock-off malfunction	Repair/replace fuel lock-off. See Chapter 4 Fuel Lock-Off.
Faulty vapor connection between the pressure regulator/converter and the mixer	Check connection. • Verify no holes in hose. • Clamps must be tight. • Look for kinked, pinched and/or collapsed hose.
Pressure regulator freezes	Check level in cooling system: • Must be full, check coolant strength • -35°F (-37°C) minimum Check coolant hoses. • Watch for kinks and/or pinched hoses. • Verify one pressure hose and one return hose. Test regulator. See Chapter 6
Vacuum leak	Check for vacuum leaks. • Between mixer and throttle body • Between throttle body and intake manifold • Between intake manifold and cylinder head

Related MIL Faults:
EST faults
ETC Sticking fault
Pre-catalyst adapts error

Cuts Out, Misses

Steady pulsation or jerking that follows engine speed, usually more pronounced as engine load increases, sometimes above 1500 rpm. The exhaust has a steady spitting sound at idle or low speed.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check fuel system specifically for plugged fuel filter, low pressure. Check for contaminated fuel. Check injector drivers. Disconnect all injector harness connectors. Use injector test light or equivalent 6-volt test light between the harness terminals of each connector and observe if light blinks while cranking. If test light fails to blink at any connector, it is a faulty injector drive circuit harness, connector, or terminal. Check lock off intermittent connection. Check dither valve operation.
Ignition system malfunction	Check for spark on the suspected cylinder(s) using a shop oscilloscope or spark tester or equivalent. If no spark, check for intermittent operation or miss. If there is a spark, remove spark plug(s) in these cylinders and check for cracks, wear, improper gap, burned electrodes, heavy deposits. Check spark plug wires by connecting ohmmeter to ends of each wire in question. If meter reads over 30,000 ohms, replace wire(s). Visually inspect distributor cap, rotor, and wires for moisture, dust, cracks, burns, etc. Spray cap and plug wires with fine water mist to check for shorts. Check engine ground wire for looseness or corrosion.
Component malfunction	Check for electromagnetic interference (EMI). A missing condition can be caused by EMI on the reference circuit. EMI can usually be detected by monitoring engine rpm with Service Tool. A sudden increase in rpm with little change in actual engine rpm indicates EMI is present. If problem exists, check routing of secondary wires and check distributor ground circuit. Check intake and exhaust manifolds for casting flash or gasket leaks.
Engine mechanical	Perform compression check on questionable cylinders. If compression is low, repair as necessary. Check base engine. Remove rocker covers and check for bent pushrods, worn rocker arms, broken valve springs, worn camshaft lobes, and valve timing. Repair as necessary.

Related MIL Faults:
EST faults
ETC Sticking fault

Poor Fuel Economy / Excessive Fuel Consumption LPG Exhaust Smell

Fuel economy, as measured during normal operation, is noticeably lower than expected. Also, economy is noticeably lower than what it has been in the past. Propane fuel smell near vehicle sets off carbon monoxide sensors.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Verify operator complaint: identify operating conditions. Check operator's driving habits: Are tires at correct pressure? Are excessively heavy loads being carried? Is acceleration too much, too often? Check air cleaner element (filter) for being dirty or plugged. Visually (physically) check vacuum hoses for splits, kinks, and proper connections as shown on application manual.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for faulty gasoline pressure regulator. Check for leaking injector. Check that dither valve duty cycle is < 15%. Check for too high propane pressure at mixer (> 1" positive pressure). Monitor Pre-catalyst O2 sensor with Service Tool.
Cooling system malfunction	Check engine coolant level. Check engine thermostat for faulty part (always open) or for wrong heat range.
Ignition system malfunction	Check ignition timing. Refer to application manual. Check for weak ignition and/or spark control. Check spark plugs. Remove spark plugs and check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. Repair or replace as necessary.
Component malfunction	Check for exhaust system restriction or leaks. Check induction system and crankcase for air leaks. Check for clogged air filter; clean or replace as required. Check FTV for housing cracks or obstructions; repair or replace as required. Check for vacuum leak. Check system vacuum hoses from regulator to FTV and mixer. Repair or replace as required.
Air/fuel mixer malfunction	Check mixer.
Pressure regulator malfunction / fuel pressure too high	Test regulator operation and pressure. See Chapter 6 Tests and Adjustments.
Engine mechanical	Check compression. Refer to Chapter 3 Engine Mechanical System.

Related MIL Faults:
Pre-catalyst O2 sensor faults / Low side driver / Dither valve duty cycle
EST faults / Fuel adapt faults / Low coolant temperature

High Idle Speed

Engine idles above the range of 750-1100 rpm.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Incorrect idle speed control	Check all hoses and gaskets for cracking, kinks, or leaks. Verify that there are no vacuum leaks. See Chapter 8 Advanced Diagnostics & Chapter 6 Tests and Adjustments
Throttle sticking	Replace throttle. See Fault Code 461: ETC_Sticking
Foot pedal sticking or incorrect pedal signal	Check pedal return spring travel for binding. Check APP function with Service Tool. Verify smooth change of APP reading with pedal movement. See Chapter 8 Advanced Diagnostics.
Engine mechanical	Check for vacuum hose leak. Check for PCV malfunction. Check for defective intake gasket.

Related MIL Faults:
ETC Sticking fault
Idle adapt out of range
MAP Sticking fault
MAP high value

Excessive Exhaust Emissions or Odors

Vehicle has high CO emissions.
NOTE: Excessive odors do not necessarily indicate excessive emissions.

PRELIMINARY CHECKS
Verify that no stored codes exist. If emission test shows excessive CO and HC, check items that cause vehicle to run rich. If emission test shows excessive NOx, check items that cause vehicle to run lean or too hot.

PROBABLE CAUSE	CORRECTIVE ACTION
Cooling system malfunction	If the Service tool indicates a very high coolant temperature and the system is running lean: • Check engine coolant level. • Check engine thermostat for faulty part (always open) or for wrong heat range. • Check fan operation
Fuel system malfunction	If the system is running rich, refer to “Diagnostic Aids” chart on the next page. If the system is running lean refer to “Diagnostic Aids” chart on the next page. Check for properly installed fuel system components. Check fuel pressure.
Ignition system malfunction	Check ignition timing. Refer to application manual. Check spark plugs, plug wires, and ignition components.
Component malfunction	Check for vacuum leaks. Check for contamination for catalytic converter (look for the removal of fuel filler neck restrictor). Check for carbon build-up. Remove carbon with quality engine cleaner. Follow instructions on label. Check for plugged PCV valve. Check for stuck or blocked PCV hose. Check for fuel in the crankcase.

Related MIL Faults:
Low side driver
Fuel adapt faults
EST faults

Diagnostic Aids for Rich / Lean Operation

SERVICE TOOL ITEM	RICH	LEAN
Pre-catalyst O2 A/ D counts	Consistently > 250	Consistently < 170
Pre-catalyst O2 sensor switching between high and low	Always high ADC	Always low ADC
Trim valve duty cycle	> 90%	< 10%
Fuel injector pulse width at idle *	< 1.0 msec.	> 8 msec.
Malfunction codes	• Pre-catalyst O2 sensor failed rich • Pre-catalyst O2 sensor high • Fuel adapts	• Pre-catalyst O2 sensor failed rich • Pre-catalyst O2 sensor high • Fuel adapts
Closed loop operation	Stuck in open loop	Stuck in open loop

(*) The duty cycle injector pulse width criteria for lean or rich operation apply only if the O2 sensor is functioning properly. If the sensor is not operating properly the criteria may be reversed.

Rich Operation

LP (Trim valve duty cycle>90%)

- Inspect hoses from AVV port (port on bottom of mixer) to trim valves and regulator for leaks or blockages, replace as necessary.
- Inspect in-line orifices for blockages (in wye), replace as necessary
- Check trim valves for proper operation, replace as necessary
- Check regulator out pressure, replace if out of spec

Gasoline (Iniector Pulse Width<1.0 msec.)

- Inspect fuel cone for damage, replace mixer assembly as necessary Gasoline (Injector Pulse Width<1.0 msec)
- Check gasoline fuel pressure
- Check injectors for sticking, replace as necessary

Lean Operation

LP (Trim valve duty cycle<10%)

- Check for vacuum leaks, replace hoses, o-rings, and gaskets as necessary
- Check balance line for blockage, replace as necessary
- Check vapor hose for restrictions, replace as necessary
- Check trim valves for proper operation, replace as necessary
- Check regulator out pressure, replace if out of spec

Gasoline (Injector Pulse Width>8 msec.)

- Check system voltage
- Check fuel pressure
- Check injectors for sticking or obstructions

Chart T-1 Restricted Exhaust System Check

Proper diagnosis for a restricted exhaust system is essential before replacement of any components. The following procedures may be used for diagnosis, depending upon engine or tool used.

Check Atpre - Catalystoxygen (O2) Sensor

1. Carefully remove pre-catalyst oxygen (O2) sensor.

2. Install exhaust backpressure tester or equivalent in place of O2 sensor using Snap-On P/N EEVPV311A kit and YA8661 adapter or Mac tool (see illustration).

3. After completing test described below, be sure to coat threads of O2 sensor with anti-seize compound prior to re-installation.

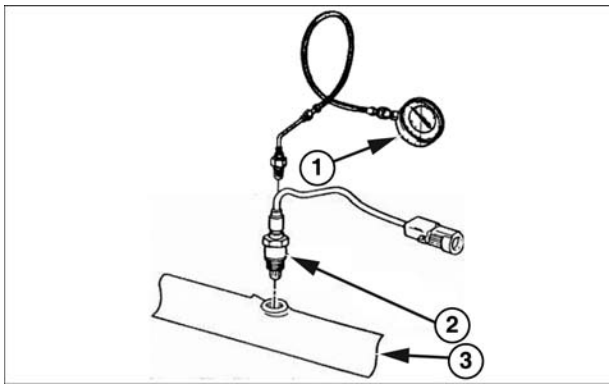


Illustration Notes

1. Backpressure gage

2. Pre-catalyst Oxygen (O2) sensor

3. Exhaust manifold

Diagnosis:

1. With the engine idling at normal operating temperature, observe the exhaust system backpressure reading on the gage. Reading should not exceed 1.25 psig (8.61 kPa).

2. Increase engine speed to 2000 rpm and observe gage. Reading should not exceed 3 psig (20.68 kPa).

3. If the backpressure at either speed exceeds specification, a restricted exhaust system is indicated.

4. Inspect the entire exhaust system for a collapsed pipe, heat distress, or possible internal damage, split welds, or cracked pipe.

5. If there are no obvious reasons for the excessive backpressure, the catalytic converter is restricted and should be replaced using current recommended procedures.

Chapter 9. ADVANCED DIAGNOSTICS

MI-07 systems are equipped with built-in fault diagnostics. Detected system faults can be displayed by the Malfunction Indicator Lamp (MIL) as Diagnostic Fault Codes (DFC) or flash codes, and viewed in detail with the use of the Service Tool software. When the ignition key is turned on, the MIL will illuminate and remain on until the engine is started. Once the engine is started, the MIL lamp will go out unless one or more fault conditions are present. If a detected fault condition exists, the fault or faults will be stored in the memory of the small engine control module (SECM). Once an active fault occurs the MIL will illuminate and remain ON. This signals the operator that a fault has been detected by the SECM.

Reading Diagnostic Fault Codes

All MI-07 fault codes are three-digit codes. When the fault codes are retrieved (displayed) the MIL will flash for each digit with a short pause (0.5 seconds) between digits and a long pause (1.2 seconds) between fault codes. A code 12 is displayed at the end of the code list.

EXAMPLE : A code 461 (ETCSticking) has been detected and the engine has shut down and the MIL has remained ON. When the codes are displayed the MIL will flash four times (4), pause, then flash six times (6), pause, then flash one time (1) This identifies a four sixty one (461), which is the ETCSticking fault. If any additional faults were stored, the SECM would again have a long pause, then display the next fault by flashing each digit. Since no other faults were stored there will be a long pause then one flash (1), pause, then two flashes (2). This identifies a twelve, signifying the end of the fault list. This list will then repeat.

Displaying Fault Codes (DFC) from SECM Memory

To enter code display mode you must turn OFF the ignition key. Now turn ON the key but do not start the engine. As soon as you turn the key to the ON position you must cycle the foot pedal by depressing it to the floor and then fully releasing the pedal (pedal maneuver). You must fully cycle the foot pedal three (3) times within five (5) seconds to enable the display codes feature of the SECM. Simply turn the key OFF to exit display mode. The code list will continue to repeat until the key is turned OFF.

Clearing Fault (DFC) Codes

To clear the stored fault codes from SECM memory you must complete the reset fault pedal maneuver.

⚠ CAUTION

Once the fault list is cleared it cannot be restored.

First turn OFF the ignition key. Now turn ON the key but do not start the engine. As soon as you turn the key to the ON position you must cycle the foot pedal by depressing it to the floor and then fully releasing the pedal (pedal maneuver). You must fully cycle the foot pedal ten (10) times within five (5) seconds to clear the fault code list of the SECM. Simply turn the key OFF to exit the reset mode. The code list is now clear and the SECM will begin storing new fault codes as they occur.

Fault Action Descriptions

Each fault detected by the SECM is stored in memory (FIFO) and has a specific action or result that takes place. Listed below are the descriptions of each fault action.

Engine Shutdown: The most severe action is an Engine Shutdown. The MIL will light and the engine will immediately shutdown, stopping spark, closing the fuel lock-off closing, and turning off the fuel pump and fuel injectors.

Delayed Engine Shutdown: Some faults, such as low oil pressure, will cause the MIL to illuminate for 30 seconds and then shut down the engine.

Cut Throttle: The throttle moves to its default position. The engine will run at idle but will not accelerate.

Cut Fuel: Fuel flow will be turned off.

Turn on MIL: The MIL will light by an active low signal provided by the SECM, indicating a fault condition. May illuminate with no other action or may be combined with other actions, depending on which fault is active.

Soft Rev Limit / Medium Rev Limit / Hard Rev Limit: System will follow various sequences to bring engine speed back to acceptable levels.

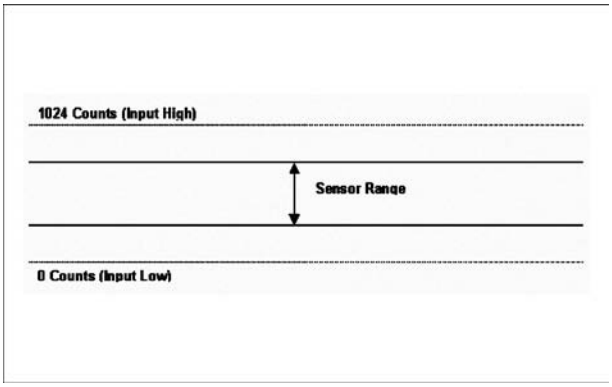
Level4 Power Limit / Level3 Power Limit / Level2 Power Limit / Level1 Power Limit: The maximum engine power output will be limited to one of four possible levels. The engine power is calculated from measured engine parameters (e.g. MAP, rpm, fuel flow, etc).

Disable Gas O2 Control: In LPG mode, closed loop correction of air fuel ratio based on the Pre-catalyst O2 sensor is disabled.

Disable Liquid O2 Control: In Gasoline mode, closed loop correction of air fuel ratio based on the Pre-catalyst O2 sensor is disabled.

Fault List Definitions

All the analog sensors in the MI-07 system have input sensor range faults. These are the coolant temperature sensor, fuel temperature sensor, throttle position sensors, pedal position sensors, manifold pressure sensor, HEGO sensors, and intake air temperature sensor. Signals to these sensors are converted into digital counts by the SECM. A low/high range sensor fault is normally set when the converted digital counts reach the minimum of 0 or the maximum of 1024 (1024 = 5.0 Vdc with ~ 204 counts per volt).



Additionally, the SECM includes software to learn the actual range of the pedal position and throttle position sensors in order to take full advantage of the sensor range. Faults are set if the learned values are outside of the normal expected range of the sensor (e.g. APP1AdaptLoMin).

Table 1. Fault List Definitions

FAULT	DESCRIPTION	CODE (MI04 CODE)
APP1AdaptHiMax	Learned full pedal end of APP1 sensor range higher than expected	641 (64)
APP1AdaptHiMin	Learned full pedal end of APP1 sensor range lowe	651
APP1AdaptLoMax	than expected	661
APP1AdaptLoMin	Learned idle end of APP1 sensor range higher than expected	631 (63)
APP1RangeHigh	Learned idle end of APP1 sensor range lower than expected	621 (62)
APP1RangeLow	APP1 sensor voltage out of range high, normally set if the APP1 signal has shorted to power or the ground for the sensor has opened	611 (61)
APP2AdaptHiMax	APP1 sensor voltage out of range low, normally set if the APP1 signal has shorted to ground, circuit has opened or sensor has failed	642 (68)
APP2AdaptHiMin	Learned full pedal end of APP2 sensor range lower than expected	652
APP2AdaptLoMax	Learned idle end of APP2 sensor range higher than expected	662
APP2AdaptLoMin	Learned idle end of APP2 sensor range lower than expected	632 (67)
APP2RangeHigh	APP2 sensor voltage out of range high, normally set if the APP2 signal has shorted to power or the ground for the sensor has opened	622 (66)
APP2RangeLow	APP2 sensor voltage out of range low, normally set if the APP2 signal has shorted to ground, circuit has opened or sensor has failed	612 (65)
APP2RangeHigh	APP2 sensor voltage out of range high, normally set if the APP2 signal has shorted to power or the ground for the sensor has opened	622 (66)
APP2RangeLow	APP2 sensor voltage out of range low, normally set if the APP2 signal has shorted to ground, circuit has opened or sensor has failed	612 (65)
APP_Sensors_Conflict	APP position sensors do no not track well, intermittent connections to APP or defective pedal assembly	691 (69)

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
CamEdgesFault	No CAM signal when engine is known to be rotating, broken CAM sensor leads or defective CAM sensor	191
CamSyncFault	Loss of synchronization on the CAM sensor, normally due to noise on the signal or an intermittent connection on the CAM sensor	192
CrankEdgesFault	No crankshaft signal when engine is known to be rotating, broken crankshaft sensor leads or defective crank sensor	193
CrankSyncFault	Loss of synchronization on the crankshaft sensor, normally due to noise on the signal or an intermittent connection on the crankshaft sensor	194
ECTOverTempFault	Engine Coolant Temperature is High. The sensor has measured an excessive coolant temperature typically due to the engine overheating.	161 (16)
ECTRangeHigh	Engine Coolant Temperature Sensor Input is High. Normally set if coolant sensor wire has been disconnected or circuit has opened to the SECM.	151 (15)
ECTRangeLow	Engine Coolant Temperature Sensor Input is Low. Normally set if the coolant sensor wire has shorted to chassis ground or the sensor has failed.	141 (14)
ECT_IR_Fault	Engine Coolant Temperature not changing as expected	171

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
EST1_Open	EST1 output open, possibly open EST1 signal or defective spark module	421 (42)
EST1_Short	EST1 output shorted high or low, EST1 signal shorted to ground or power or defective spark module	431
EST2_Open	EST2 output open, possibly open EST2 signal or defective spark module	422
EST2_Short	EST2 output shorted high or low, EST2 signal shorted to ground or power or defective spark module	432
EST3_Open	EST3 output open, possibly open EST3 signal or defective spark module	423
EST3_Short	EST3 output shorted high or low, EST3 signal shorted to ground or power or defective spark module	433
EST4_Open	EST4 output open, possibly open EST4 signal or defective spark module	424
EST4_Short	EST4 output shorted high or low, EST4 signal shorted to ground or power or defective spark module	434
EST5_Open	EST5 output open, possibly open EST5 signal or defective spark module	425
EST5_Short	EST5 output shorted high or low, EST5 signal shorted to ground or power or defective spark module	435
EST6_Open	EST6 output open, possibly open EST6 signal or defective spark module	426
EST6_Short	EST6 output shorted high or low, EST6 signal shorted to ground or power or defective spark module	436
EST7_Open	EST7 output open, possibly open EST7 signal or defective spark module	427
EST7_Short	EST7 output shorted high or low, EST7 signal shorted to ground or power or defective spark module	437
EST8_Open	EST8 output open, possibly open EST8 signal or defective spark module	428
EST8_Short	EST8 output shorted high or low, EST8 signal shorted to ground or power or defective spark module	438

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
ETCSpringTest	Electronic Throttle Control Spring Return Test has Failed. The SECM will perform a safety test of the throttle return spring following engine shutdown. If this spring has become weak the throttle will fail the test and set the fault. **NOTE:** Throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.	481 (28)
ETC_Open_Fault	Electronic Throttle Control Driver has failed. Normally set if either of the ETC driver signals have opened or become disconnected, electronic throttle or SECM is defective.	471
ETC_Sticking	Electronic Throttle Control is Sticking. This can occur if the throttle plate (butterfly valve) inside the throttle bore is sticking. The plate sticking can be due to some type of obstruction; a loose throttle plate or worn components shaft bearings. **NOTE:** Throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.	461 (26)
FuelSelectConflict	Conflict in fuel select signals, normally set if one or both of the fuel select signals are shorted to ground	181
FuelTempRangeHigh	Fuel Temperature Sensor Input is High. Normally set if the fuel temperature sensor wire has been disconnected or the circuit has opened to the SECM.	932
FuelTempRangeLow	Fuel Temperature Sensor Input is Low. Normally set if the fuel temperature sensor wire has shorted to chassis ground or the sensor has failed.	931

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
GasFuelAdaptRangeHi	In LPG mode, system had to adapt lean more than expected	731 (73)
GasFuelAdaptRangeLo	In LPG mode, system had to adapt rich more than expected	721 (72)
GasO2FailedLean	Pre-catalyst O2 sensor indicates extended lean operation on LPG	751
GasO2FailedRich	Pre-catalyst O2 sensor indicates extended rich operation on LPG	771 (77)
GasO2NotActive	Pre-catalyst O2 sensor inactive on LPG, open O2 sensor signal or heater leads, defective O2 sensor, or defective FTVs	741 (74)
GasPostO2FailedRich	Post-catalyst O2 sensor control on LPG has reached rich limit and sensor still reads to lean. This could be caused by oxygen leak before or just after sensor, catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre-O2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets.	772
GasPostO2FailedLean	Post-catalyst O2 sensor control on LPG has reached lean limit and sensor still reads to rich. This could be caused by catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre-O2 sensor faults are set diagnose, these first and after correcting these faults recheck if this fault sets.	752
GasPostO2Inactive	Post-catalyst O2 sensor control on LPG has sensed the O2 sensor is not responding as expected. If any Pre-O2 sensor faults are set diagnose these first and after correcting these faults recheck if this fault sets. Possible causes for this fault are sensor disconnected, sensor heater failed, sensor element failed, heater relay, or SECM control of heater relay is disconnected or failed.	742
Reserved for Future Use		743

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
HbridgeFault_ETC	(Electronic Throttle Control Driver has Failed) Indeterminate fault on Hbridge driver for Electronic Throttle Control. Possibly either ETC+ or ETC- driver signals have been shorted to ground	491 (29)
HardOverspeed	Engine speed has exceeded the third level (3 of 3) of overspeed protection	571 (57)
IATRangeHigh	Intake Air Temperature Sensor Input is High normally set if the IAT temperature sensor wire has been disconnected, the circuit has opened to the SECM, or a short to Vbatt has occurred.	381 (38)
IATRangeLow	Intake Air Temperature Sensor Input is Low normally set if the IAT temperature sensor wire has shorted to chassis ground or the sensor has failed.	371 (37)
IAT_IR_Fault	Intake Air Temperature not changing as expected	391
Inj1Open	Gasoline Injector 1 open circuit, broken injector 1 wire or defective injector	131
Inj2Open	Gasoline Injector 2 open circuit, broken injector 2 wire or defective injector	132
Inj3Open	Gasoline Injector 3 open circuit, broken injector 3 wire or defective injector	133
Inj4Open	Gasoline Injector 4 open circuit, broken injector 4 wire or defective injector	134
Inj5Open	Gasoline Injector 5 open circuit, broken injector 5 wire or defective injector	135
Inj6Open	Gasoline Injector 6 open circuit, broken injector 6 wire or defective injector	136
Inj7Open	Gasoline Injector 7 open circuit, broken injector 7 wire or defective injector	137
Inj8Open	Gasoline Injector 8 open circuit, broken injector 8 wire or defective injector	138
LSDFault_CSValve	Cold Start Valve Fault, signal has opened or shorted to ground or power or defective cold start valve	713

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
LSDFault_CheckEngine	Check Engine Lamp Fault, signal has opened or shorted to ground or power or defective check engine lamp	714
LSDFault_CrankDisable	Crank Disable Fault, signal has opened or shorted to ground or power or defective crank disable relay	715
LSDFault_Dither1	Dither Valve 1 Fault, signal has opened or shorted to ground or power or defective dither 1 valve	711 (71)
LSDFault_Dither2	Dither Valve 2 Fault, signal has opened or shorted to ground or power or defective dither 2 valve	712
LSDFault_FuelPump	Fuel Pump Fault, signal has opened or shorted to ground or power or defective fuel pump	716
LSDFault_LockOff	Fuel lock off Valve Fault, signal has opened or shorted to ground or power or defective Fuel lock off valve	717
LSDFault_MIL	Malfunction Indicator Lamp Fault, signal has opened or shorted to ground or power or defective MIL lamp	718
LiqFuelAdaptRangeHi	In Gasoline mode, system had to adapt rich more than expected	821
LiqFuelAdaptRangeLow	In Gasoline mode, system had to adapt lean more than expected	831
LiqO2FailedLean	Pre-catalyst O2 sensor indicates extended lean operation on gasoline	851
LiqO2FailedRich	Pre-catalyst O2 sensor indicates extended rich operation on gasoline	871
LiqO2NotActive	Pre-catalyst O2 sensor inactive on gasoline, open O2 sensor signal or heater leads, defective O2 sensor	841
LiqPostO2FailedRich	Post-catalyst O2 sensor control on gasoline has reached rich limit and sensor still reads to lean. This could be caused by oxygen leak before or just after sensor, catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre-O2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets.	872
LiqPostO2FailedLean	Post catalyst O2 sensor control on gasoline has reached lean limit and sensor still reads to rich. This could be caused by catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre O2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets.	852

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
LiqPostO2Inactive	Post-catalyst O2 sensor control on gasoline has sensed the O2 sensor is not responding as expected. If any Pre-O2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets. Possible causes for this fault are sensor disconnected, sensor heater failed, sensor element failed, heater relay, or SECM control of heater relay is disconnected or failed.	842
Reserved		843
LowOilPressureFault	Low engine oil pressure	521 (52)
MAPRangeHigh	Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed.	342
MAPRangeLow	Manifold Absolute Pressure Sensor Input is Low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	332
MAPTimeRangeHigh	Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed	341 (34)
MAPTimeRangeLow	Manifold Absolute Pressure Sensor Input is Low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	331 (33)
MAP_IR_HI	MAP sensor indicates higher pressure than expected	351
MAP_IR_LO	MAP sensor indicates lower pressure than expected	352
MAP_STICKING	MAP sensor not changing as expected	353
MediumOverspeed	Engine speed has exceeded the second level (2 of 3) of overspeed protection	572
O2RangeHigh	Pre -catalyst O2 sensor voltage out of range high, sensor signal shorted to power	921
O2RangeLow	Pre-catalyst O2 sensor voltage out of range low, sensor signal shorted to ground	911
O2_PostCatRangeHigh	Post-catalyst O2 sensor voltage out of range high, sensor signal shorted to voltage source (5V or battery)	922
O2_PostCatRangeLow	Post -catalyst O2 sensor voltage out of range low, sensor signal shorted to ground	912
SensVoltRangeHigh	Sensor reference voltage XDRP too high	561 (56)

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
SensVoltRangeLow	Sensor reference voltage XDRP too low	551 (55)
ServiceFault1	Service Interval 1 has been reached	991
ServiceFault2	Service Interval 2 has been reached	992
ServiceFault3	Service Interval 3 has been reached	993
ServiceFault4	Service Interval 4 has been reached—time to replace HEGO sensors	994
ServiceFault5	Service Interval 5 has been reached—time to replace engine timing belt	995
SoftOverspeed	Engine speed has exceeded first level (1 of 3) of overspeed protection	573
TPS1AdaptHiMin	Learned WOT end of TPS1 sensor range lower than expected	271
SysVoltRangeHigh	System voltage too high	541 (54)
SysVoltRangeLow	System voltage too low	531 (53)
TPS1AdaptHiMax	Learned WOT end of TPS1 sensor range higher than expected	251 (25)
TPS1AdaptHiMin	Learned WOT end of TPS1 sensor range lower than expected	271
TPS1AdaptLoMax	Learned closed throttle end of TPS1 sensor range higher than expected	281
TPS1AdaptLoMin	Learned closed throttle end of TPS1 sensor range lower than expected	241 (24)
TPS1RangeHigh	TPS1 sensor voltage out of range high, normally set if the TPS1 signal has shorted to power or ground for the sensor has opened	231 (23)
TPS1RangeLow	TPS1 sensor voltage out of range low, normally set if TPS1 signal has shorted to ground, circuit has opened or sensor has failed	221 (22)
TPS2AdaptHiMax	Learned WOT end of TPS2 sensor range higher than expected	252
TPS2AdaptHiMin	Learned WOT end of TPS2 sensor range lower than expected	272
TPS2AdaptLoMax	Learned closed throttle end of TPS2 sensor range higher than expected	282
TPS2AdaptLoMin	Learned closed throttle end of TPS2 sensor range lower than expected	242
TPS2RangeHigh	TPS2 sensor voltage out of range high, normally set if the TPS2 signal has shorted to power or ground for the sensor has opened	232

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
TPS2RangeLow	TPS2 sensor voltage out of range low, normally set if TPS2 signal has shorted to ground, circuit has opened or sensor has failed	222
TPS_Sensors_Conflict	TPS sensors differ by more than expected amount. **NOTE:** The TPS is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly	291
TransOilTemp	Excessive transmission oil temperature	933

Table 2. Diagnostic Fault Codes (Flash Codes)

DFC	PROBABLE FAULT	FAULT ACTION*	CORRECTIVE ACTION FIRST CHECK
12	**NONE** Signifies the end of one pass through the fault list	NONE	None, used as end of the fault list identification
131	**Inj1Open** Gasoline Injector 1 open circuit, broken injector 1 wire or defective injector	TurnOnMil	Check INJ1 wiring for an open circuit SECM (Signal) A5 to Injector 1 Pin A Switched 12V to Injector 1 Pin B Check Injector 1 Resistance, 12 to14 ohms (cold)
132	**Inj2Open** Gasoline Injector 2 open circuit, broken injector 2 wire or defective injector	TurnOnMil	Check INJ2 wiring for an open circuit SECM (Signal) A8 to Injector 2 Pin A Switched 12V to Injector 2 Pin B Check Injector 2 Resistance, 12 to14 ohms (cold)
133	**Inj3Open** Gasoline Injector 3 open circuit, broken injector 3 wire or defective injector	TurnOnMil	Check INJ3 wiring for an open circuit SECM (Signal) A4 to Injector 3 Pin A Switched 12V to Injector 3 Pin B Check Injector 3 Resistance, 12 to14 ohms (cold)
134	**Inj4Open** Gasoline Injector 4 open circuit, broken injector 4 wire or defective injector	TurnOnMil	Check INJ4 wiring for an open circuit SECM (Signal) A7 to Injector 4 Pin A Switched 12V to Injector 4 Pin B Check Injector 4 Resistance, 12 to14 ohms (cold)
135 Not Used	**Inj5Open** Gasoline Injector 5 open circuit, broken injector 5 wire or defective injector	None	N/A
136 Not Used	**Inj6Open** Gasoline Injector 6 open circuit, broken injector 6 wire or defective injector	None	N/A
137 Not Used	**Inj7Open** Gasoline Injector 7 open circuit, broken injector 7 wire or defective injector	None	N/A
138 Not Used	**Inj8Open** Gasoline Injector 8 open circuit, broken injector 8 wire or defective injector	None	N/A
141 (14)	**ECTRangeLow** Coolant Sensor failure or shorted to GND	TurnOnMil	Check ECT sensor connector and wiring for a short to GND SECM (Signal) Pin B15 To ECT Pin 3 SECM (Sensor GND) Pin B1 to ECT Pin 1 SECM (Sensor GND) Pin A16, B17
151 (15)	**ECTRangeHigh** Coolant sensor disconnected or open circuit	(1) TurnOnMil (2) Delayed Engine Shutdown (3) CheckEngineLight	Check if ECT sensor connector is disconnected or for an open ECT circuit SECM (Signal) Pin B15 to ECT Pin 3 SECM (Sensor GND) Pin B1 to ECT Pin 1

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
161 (16)	**ECTOverTempFault** Engine coolant temperature is high. The sensor has measured an excessive coolant temperature typically due to the engine overheating.	(1) TurnOnMil (2) Delayed Engine Shutdown (3) CheckEngineLight	Check coolant system for radiator blockage, proper coolant level and for leaks in the system. Possible ECT short to GND, check ECT signal wiring SECM (Signal) Pin B15 to ECT Pin 3 SECM (Sensor GND) Pin B1 to ECT Pin 1 SECM (System GND) Pin A16, B17 Check regulator for coolant leaks
171	**ECT_IR_Fault** Engine coolant temperature not changing as expected	None	Check for coolant system problems, e.g. defective or stuck thermostat
181	**FuelSelectConflict** Conflict in fuel select signals, normally set if both of the fuel select signals are shorted to ground	TurnOnMil	Check fuel select switch connection for a short to GND SECM (SIGNAL) Pin A12 SECM (SIGNAL) Pin A15 SECM (Sensor GND) Pin B1
191	**CamEdgesFault** No CAM signal when engine is known to be rotating, broken crankshaft sensor leads or defective CAM sensor	None	Check CAM sensor connections SECM (SIGNAL) Pin B10 to CAM sensor Pin 2 SECM (Sensor GND) Pin B1 to CAM sensor Pin 3 Switched 12V to CAM sensor Pin 1 Check for defective CAM sensor
192	**CamSyncFault** Loss of synchronization on the CAM sensor, normally due to noise on the signal or an intermittent connection on the CAM sensor	None	Check CAM sensor connections SECM (SIGNAL) Pin B10 to CAM sensor Pin 2 SECM (Sensor GND) Pin B1 to CAM sensor Pin 3 Switched 12V to CAM sensor Pin 1 Check for defective CAM sensor
193	**CrankEdgesFault** No crankshaft signal when engine is known to be rotating, broken crankshaft sensor leads or defective crank sensor	None	Check Crankshaft sensor connections SECM (SIGNAL) Pin B5 to Crank sensor Pin 3 SECM (Sensor GND) PIN B1 to Crank sensor Pin 2 Switched 12V to Crank sensor Pin 1 Check for defective Crank sensor
194	**CrankSyncFault** Loss of synchronization on the crankshaft sensor, normally due to noise on the signal or an intermittent connection on the crankshaft sensor	None	Check Crankshaft sensor connections SECM (SIGNAL) Pin B5 to Crank sensor Pin 3 SECM (Sensor GND) Pin B1 to Crank sensor Pin 2 Switched 12V to Crank sensor Pin 1 Check for defective Crank sensor

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
221 (22)	**TPS1RangeLow** TPS1 sensor voltage out of range low, normally set if the TPS1 signal has shorted to ground, circuit has opened or sensor has failed	TurnOnMil	Check throttle connector connection and TPS1 sensor for an open circuit or short to GND SECM Pin B23 (signal) to ETC Pin 6 SECM Pin B1 (sensor GND) to ETC Pin 2 SECM (system GND) Pin A16, B17
222	**TPS2RangeLow** TPS2 sensor voltage out of range low, normally set if the TPS2 signal has shorted to ground, circuit has opened or sensor has failed	TurnOnMil	Check throttle connector connection and TPS2 sensor for an open circuit or short to GND SECM Pin B4 (signal) to ETC Pin 5 SECM Pin B1 (sensor GND) to ETC Pin 2 SECM (system GND) Pin A16, B17
231 (23)	**TPS1RangeHigh** TPS1 sensor voltage out of range high, normally set if the TPS1 signal has shorted to power or the ground for the sensor has opened	TurnOnMil	Check throttle connector and TPS1 sensor wiring for a shorted circuit SECM Pin B23 (signal) to ETC Pin 6 SECM Pin B1 (sensor GND) to ETC Pin 2
232	**TPS2RangeHigh** TPS2 sensor voltage out of range high, normally set if the TPS2 signal has shorted to power or the ground for the sensor has opened	TurnOnMil	Check throttle connector and TPS1 sensor wiring for a shorted circuit SECM Pin B4 (signal) to ETC Pin 5 SECM Pin B1 (sensor GND) to ETC Pin 2
241 (24)	**TPS1AdaptLoMin** Learned closed throttle end of TPS1 sensor range lower than expected	None	Check the throttle connector and pins for corrosion. To check the TPS disconnect the throttle connector and measure the resistance from: TPS Pin 2 (GND) to Pin 6 (TPS1 SIGNAL) (0.7Ω ± 30%) TPS Pin 3 (PWR) to Pin 6 (TPS1 SIGNAL) (1.4Ω ± 30%)
242	**TPS2AdaptLoMin** Learned closed throttle end of TPS2 sensor range lower than expected	None	Check the throttle connector and pins for corrosion. To check the TPS disconnect the throttle connector and measure the resistance from: TPS Pin 2 (GND) to Pin 5 (TPS2 SIGNAL) (1.3KΩ ± 30%) TPS PIN 3 (PWR) to PIN 5 (TPS2 SIGNAL) (0.6KΩ ± 30%)
251 (25)	**TPS1AdaptHiMax** Learned WOT end of TPS1 sensor range higher than expected	None	N/A
252	**TPS2AdaptHiMax** Learned WOT end of TPS2 sensor range higher than expected	None	N/A
271	**TPS1AdaptHiMin** Learned WOT end of TPS1 sensor range lower than expected	None	N/A

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
272	**TPS2AdaptHiMin** Learned WOT end of TPS2 sensor range lower than expected	None	N/A
281	**TPS1AdaptLoMax** Learned closed throttle end of TPS1 sensor range higher than expected	None	N/A
282	**TPS2AdaptLoMax** Learned closed throttle end of TPS2 sensor range higher than expected	None	N/A
291	**TPS_Sensors_Conflict** TPS sensors differ by more than expected amount NOTE: The TPS is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.	(1) TurnOnMil (2) Engine Shutdown	Perform checks for DFCs 241 & 242
331 (33)	**MAPTimeRangeLow** Manifold Absolute Pressure sensor input is low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	None	Check TMAP connector and MAP signal wiring for an open circuit TMAP Pin 4 to SECM Pin B18 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) TMAP Pin 3 to SECM Pin B24 (XDRP +5 Vdc) Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1(GND) to Pin 4 (pressure signal KPA) (2.4kΩ - 8.2k) TMAP Pin 3 (power) to Pin 4 (pressure signal KPA) (3.4kΩ - 8.2k)
332	**MAPRangeLow** Manifold Absolute Pressure sensor input is low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	(1) TurnOnMil (2) CutThrottle	Check TMAP connector and MAP signal wiring for an open circuit TMAP Pin 4 to SECM Pin B18 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) TMAP Pin 3 to SECM Pin B24 (XDRP +5 Vdc) Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1(GND) to Pin 4 (pressure signal KPA) (2.4kΩ - 8.2kΩ) TMAP Pin 3 (power) to Pin 4 (pressure signal KPA) (3.4k Ω- 8.2kΩ)

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
341 (34)	**MAPTimeRangeHigh** Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed.	None	Check TMAP connector and MAP signal wiring for a shorted circuit TMAP Pin 4 to SECM Pin B18 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) TMAP Pin 3 to SECM Pin B24 (XDRP +5 Vdc) Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1(GND) to Pin 4 (pressure signal KPA) (2.4kΩ - 8.2kΩ) TMAP Pin 3 (power) to Pin 4 (pressure signal KPA) (3.4kΩ - 8.2kΩ)
342	**MAPRangeHigh** Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed	(1) TurnOnMil (2) CutThrottle	Check TMAP connector and MAP signal wiring for a shorted circuit TMAP Pin 4 to SECM Pin B18 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) TMAP Pin 3 to SECM Pin B24 (XDRP +5 Vdc) Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1(GND) to Pin 4 (pressure signal KPA) (2.4kΩ - 8.2kΩ) TMAP Pin 3 (power) to Pin 4 (pressure signal KPA) (3.4kΩ - 8.2kΩ)
351	**MAP_IR_HI** MAP sensor indicates higher pressure than expected	None	Check for vacuum leaks. Check that TMAP sensor is mounted properly. Possible defective TMAP sensor.
352	**MAP_IR_LO** MAP sensor indicates lower pressure than expected	None	Possible defective TMAP sensor.
353	**MAP_STICKING** MAP sensor not changing as expected	None	Check that TMAP sensor is mounted properly. Possible defective TMAP sensor.
371 (37)	**IATRangeLow** Intake Air Temperature Sensor Input is Low normally set if the IAT temperature sensor wire has shorted to chassis ground or the sensor has failed.	TurnOnMil	Check TMAP connector and IAT signal wiring for a shorted circuit TMAP Pin 2 to SECM Pin B12 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) To check the IAT sensor of the TMAP disconnect the TMAP connector and measure the IAT resistance Resistance is approx 2400 ohms at room temperature.

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION, FIRST CHECK
381 (38)	**IATRangeHigh** Intake Air Temperature Sensor Input is High normally set if the IAT temperature sensor wire has been disconnected or the circuit has opened to the SECM.	TurnOnMil	Check TMAP connector and IAT signal wiring for a shorted circuit TMAP Pin 2 to SECM Pin B12 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) To check the IAT sensor of the TMAP disconnect the TMAP connector and measure the IAT resistance Resistance is approx 2400 ohms at room temperature.
391	**IAT_IR_Fault** Intake Air Temperature not changing as expected	None	Check connections to TMAP sensor. Check that TMAP sensor is properly mounted to manifold.
421	**EST1_Open EST1** output open, possibly open EST1 signal or defective spark module	TurnOnMil	Check coil driver wiring and connector for open circuit SECM Pin A9 (EST1) to OEM ignition system. See application note. Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details
422	**EST2_Open EST2** output open, possibly open EST2 signal or defective spark module	TurnOnMil	Check coil driver wiring and connector for open circuit SECM Pin A10 (EST2) to OEM ignition system. See application note. Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details.
423	**EST3_Open EST3** output open, possibly open EST3 signal or defective spark module	TurnOnMi	Check coil driver wiring and connector for open circuit SECM Pin A3 (EST3) to OEM ignition system. See application note. Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details.

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
424	**EST4_Open EST4** output open, possibly open EST4 signal or defective spark module	TurnOnMil	Check coil driver wiring and connector for open circuit SECM Pin A6 (EST4) to OEM ignition system. See application manual. Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details.
425	**EST5_Open EST5** output open, possibly open EST5 signal or defective spark module	None	N/A
426	**EST6_Open EST6** output open, possibly open EST6 signal or defective spark module	None	N/A
427	**EST7_Open EST7** output open, possibly open EST7 signal or defective spark module	None	N/A
428	**EST8_Open EST8** output open, possibly open EST8 signal or defective spark module	None	N/A
431	**EST1_Short EST1** output shorted high or low, EST1 signal shorted to ground or power or defective spark module	TurnOnMil	Check coil driver wiring and connector for shorts SECM Pin A9 (EST1) to ignition module Pin D (4-pin connector) Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details.

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
432	**EST2_Short EST2** output shorted high or low, EST2 signal shorted to ground or power or defective spark module	TurnOnMil	Check coil driver wiring and connector for shorts SECM Pin A10 (EST2) to ignition module Pin D (4-pin connector) Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details.
433	**EST3_Short EST3** output shorted high or low, EST3 signal shorted to ground or power or defective spark module	TurnOnMil	Check coil driver wiring and connector for shorts SECM Pin A3 (EST3) to ignition module Pin D (4-pin connector) Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details.
434	**EST4_Short EST4** output shorted high or low, EST4 signal shorted to ground or power or defective spark module	TurnOnMil	Check coil driver wiring and connector for shorts SECM Pin A6 (EST4) to ignition module Pin D (4-pin connector) Verify GND on ignition module Pin A (of both connectors) Verify +12 Vdc on ignition module Pin B (of both connectors) Refer to application manual for specific engine details.
435	**EST5_Short EST5** output shorted high or low, EST5 signal shorted to ground or power or defective spark module	None	N/A
436	**EST6_Short EST6** output shorted high or low, EST6 signal shorted to ground or power or defective spark module	None	N/A

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
437	**EST7_Short** EST7 output shorted high or low, EST7 signal shorted to ground or power or defective spark module	None	N/A
438	**EST8_Short** EST8 output shorted high or low, EST8 signal shorted to ground or power or defective spark module	None	N/A
461 (26)	**ETC_Sticking** Electronic Throttle Control is sticking. This can occur if the throttle plate (butterfly valve) inside the throttle bore is sticking. The plate sticking can be due to some type of obstruction, a loose throttle plate, or worn components shaft bearings. NOTE: The throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly	(1)TurnOnMil (2) EngineShutdown (3)CutThrottle	Check for debris or obstructions inside the throttle body Check throttle-plate shaft for bearing wear Check the ETC driver wiring for an open circuit SECM Pin A17 to ETC + Pin 1 SECM Pin A18 to ETC - Pin 4 Check the ETC internal motor drive by disconnecting the throttle connector and measuring the motor drive resistance at the throttle TPS Pin 1 (+DRIVER) to Pin 4 (-DRIVER) ~3.0-4.0
471	**ETC_Open_Fault** Electronic Throttle Control Driver has failed, normally set if either of the ETC driver signals have opened or become disconnected, electronic throttle or SECM is defective.	None	Check the ETC driver wiring for an open circuit SECM Pin A17 to ETC + Pin 1 SECM Pin A18 to ETC - Pin 4 Check the ETC internal motor drive by disconnecting the throttle connector and measuring the motor drive resistance at the throttle TPS Pin 1 (+DRIVER) to Pin 4 (-DRIVER) ~3.0-4.0
481 (28)	**ETCSpringTest** Electronic Throttle Control Driver has failed, normally set if either of the ETC driver signals have opened or become disconnected, electronic throttle or SECM is defective. Electronic Throttle Control Spring Return Test has failed. The SECM will perform a safety test of the throttle return spring following engine shutdown. If this spring has become weak the throttle will fail the test and set the fault. NOTE: The throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.	(1) TurnOnMil (2) EngineShutdown	Perform throttle spring test by cycling the ignition key and re-check for fault

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
491 (29)	**HbridgeFault_ETC** Electronic Throttle Control Driver has failed. Indeterminate fault on Hbridge driver for electronic throttle control. Possibly either ETC+ or ETC- driver signals have been shorted to ground	TurnOnMil	Check ETC driver wiring for a shorted circuit SECM Pin A17 to ETC + Pin 1 SECM Pin A18 to ETC - Pin 4 Check the ETC internal motor drive by disconnecting the throttle connector and measuring the motor drive resistance at the throttle TPS Pin 1 (+DRIVER) to Pin 4 (-DRIVER) ~3.0-4.0Ω
521 (52)	**LowOilPressureFault** Low engine oil pressure	(1) TurnOnMil (2) DelayedEngine Shutdown (3) CheckEngine Light	Check engine oil level Check electrical connection to the oil pressure switch SECM Pin B9 to Oil Pressure Switch
531 (53)	**SysVoltRangeLow** System voltage too low	TurnOnMil	Check battery voltage • Perform maintenance check on electrical connections to the battery and chassis ground • Check battery voltage during starting and with the engine running to verify charging system and alternator function • Measure battery power at SECM with a multimeter (with key on) SECM Pin A23 (DRVP) to SECM Pin A16 (DRVG) SECM Pin A23 (DRVP) to SECM Pin B17 (DRVG)
541 (54)	**SysVoltRangeHigh** System voltage too high	TurnOnMil	Check battery and charging system voltage •Check battery voltage during starting and with the engine running •Check voltage regulator, alternator, and charging system •Check battery and wiring for overheating and damage • Measure battery power at SECM with a multimeter (with key on) SECM Pin A23 (DRVP) to SECM Pin A16 (DRVG) SECM Pin A23 (DRVP) to SECM Pin B17 (DRVG)

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
551 (55)	**SensVoltRangeLow** Sensor reference voltage XDRP too low	(1) TurnOnMil (2) EngineShutdown	Measure transducer power at the TMAP connector with a multimeter TMAP Pin 3 XDRP +5 Vdc to TMAP Pin 1 XDRG GND Verify transducer power at the SECM with a multimeter SECM Pin B24 +5 Vdc to SECM Pin B1 XDRG GND Verify transducer power at ETC with a multimeter ETC Pin 3 XDRP PWR to ETC Pin 2 XDRG GND Verify transducer power to the foot pedal with a multimeter.
561 (56)	**SensVoltRangeHigh** Sensor reference voltage XDRP too high	(1) TurnOnMil (2) EngineShutdown	Measure transducer power at the TMAP connector with a multimeter TMAP Pin 3 XDRP +5 Vdc to TMAP Pin 1 XDRG GND Verify transducer power at the SECM with a multimeter SECM Pin B24 +5 Vdc to SECM Pin B1 XDRG GND Verify transducer power at ETC with a multimeter ETC Pin 3 XDRP PWR to ETC Pin 2 XDRG GND Verify transducer power to the foot pedal with a multimeter.
571 (57)	**HardOverspeed** Engine speed has exceeded the third level (3 of 3) of overspeed protection	(1) TurnOnMil (2) HardRevLimit	Usually associated with additional ETC faults Check for ETC Sticking or other ETC faults Verify if the lift truck was motored down a steep grade
572	**MediumOverspeed** Engine speed has exceeded the second level (2 of 3) of overspeed protection	(1) TurnOnMil (2) MediumRevLimit	Usually associated with additional ETC faults Check for ETC Sticking or other ETC faults Verify if the lift truck was motored down a steep grade
573	**SoftOverspeed** Engine speed has exceeded the first level (1 of 3) of overspeed protection	(1) TurnOnMil (2) SoftRevLimit	Usually associated with additional ETC faults Check for ETC Sticking or other ETC faults Verify if the lift truck was motored down a steep grade
611 (61)	**APP1RangeLow** APP1 sensor voltage out of range low, normally set if the APP1 signal has shorted to ground, circuit has opened or sensor has failed	(1) TurnOnMil (2) CheckEngineLight	Check foot pedal connector Check APP1 signal at SECM PIN B7

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
612 (65)	**APP2RangeLow** APP2 sensor voltage out of range low, normally set if the APP2 signal has shorted to ground, circuit has opened or sensor has failed	TurnOnMil	Check foot pedal connector • Check APP2 signal at SECM PIN B16
621 (62)	**APP1RangeHigh** APP1 sensor voltage out of range high, normally set if the APP1 signal has shorted to power or the ground for the sensor has opened	(1) TurnOnMil (2) CheckEngine Light	Check foot pedal connector • Check APP1 signal at SECM PIN B7
622 (66)	**APP2RangeHigh** APP2 sensor voltage out of range high, normally set if the APP2 signal has shorted to power or the ground for the sensor has opened	TurnOnMil	Check foot pedal connector • Check APP2 signal at SECM PIN B16
631 (63)	**APP1AdaptLoMin** Learned idle end of APP1 sensor range lower than expected	None	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP1 signal at SECM Pin B7
632 (67)	**APP2AdaptLoMin** Learned idle end of APP2 sensor range lower than expected	None	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP2 signal at SECM Pin B16
641 (64)	**APP1AdaptHiMax** Learned full pedal end of APP1 sensor range higher than expected	None	N/A
642 (68)	**APP2AdaptHiMax** Learned full pedal end of APP2 sensor range higher than expected	None	N/A
651	**APP1AdaptHiMin** Learned full pedal end of APP1 sensor range lower than expected	None	N/A
652	**APP2AdaptHiMin** Learned full pedal end of APP2 sensor range lower than expected	None	N/A
661	**APP1AdaptLoMax** Learned idle end of APP1 sensor range higher than expected	None	N/A
662	**APP2AdaptLoMax** Learned idle end of APP2 sensor range higher than expected	None	N/A
691 (69)	**APP_Sensors_Conflict** APP position sensors do no not track well, intermittent connections to APP or defective pedal assembly	(1) TurnOnMil (2) Level1PowerLimit	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP1 signal at SECM Pin B7 • Cycle the pedal several times and check APP2 signal at SECM Pin B16

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
711 (71)	**LSDFault_Dither1** Dither Valve 1 Fault, signal has opened or shorted to ground or power or defective dither 1 valve	TurnOnMil	Check FTV1 for an open wire or FTV connector being disconnected FTV1 Pin 1 (signal) to SECM Pin A1 FTV1 Pin 2 (power) to SECM (DRVP) Pin A23 Check FTV1 for an open coil by disconnecting the FTV connector and measuring the resistance (~26 Ω ± 2 Ω)
712	**LSDFault_Dither2** Dither Valve 2 Fault, signal has opened or shorted to ground or power or defective dither 2 valve	TurnOnMil	Check FTV1 for an open wire or FTV connector being disconnected or signal shorted to GND FTV2 Pin 1 (signal) to SECM Pin A2 FTV2 Pin 2 (power) to SECM (DRVP) Pin A23 Check FTV1 for an open coil by disconnecting the FTV connector and measuring the resistance (~26 Ω ± 2 Ω)
714	**LSDFault_CheckEngine** Check Engine Lamp Fault, signal has opened or shorted to ground or power or defective check engine lamp	None	Check 'Check Engine Lamp' for an open wire or shorted to GND
715	**LSDFault_CrankDisable** Crank Disable Fault, signal has opened or shorted to ground or power or defective crank disable relay	None	N/A
717	**LSDFault_LockOff** Fuel lock off Valve Fault, signal has opened or shorted to ground or power or defective Fuel lock off valve	TurnOnMil	Check fuel lock off valve for an open wire or connector being disconnected or signal shorted to GND Lockoff Pin B (signal) to SECM Pin A11 Lockoff Pin A (power) to SECM (DRVP) Pin A23 Check CSV for an open coil by disconnecting the CSV connector and measuring the resistance (~26 Ω ± 3 Ω)
718	**LSDFault_MIL** Malfunction Indicator Lamp Fault, signal has opened or shorted to ground or power or defective MIL lamp	None	Check MIL lamp for an open wire or short to GND.
721 (72)	**GasFuelAdaptRangeLo** In LPG mode, system had to adapt rich more than expected	TurnOnMil	Check for vacuum leaks. Check fuel trim valves, e.g. leaking valve or hose Check for missing orifice(s).

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
731 (73)	**GasFuelAdaptRangeHi** In LPG mode, system had to adapt lean more than expected	TurnOnMil	Check fuel trim valves, e.g. plugged valve or hose. Check for plugged orifice(s).
741 (74)	**GasO2NotActive** Pre-catalyst O2 sensor inactive on LPG, open O2 sensor signal or heater leads, defective O2 sensor	(1) TurnOnMil (2) DisableGas O2Ctrl	Check that Pre-catalyst O2 sensor connections are OK. O2 (signal) Pin 3 to SECM Pin B13 O2 Pin 2 (HEATER GND) to SECM (DRVG GNG) Pins A16, B17 O2 Pin 1 (HEATER PWR) to SECM (DRVP + 12V) Pin A23 Verify O2 sensor heater circuit is operating by measuring heater resistance (2.1 Ω ± 0.4 Ω) O2 Pin 2 (HEATER GND) to Pin 1 (HEATER PWR)
742	**GasPostO2NotActive** Post-catalyst O2 sensor inactive on LPG, open O2 sensor signal or heater leads, defective O2 sensor.	(1) TurnOnMil (2) DisableGasPost O2Ctrl	Check that Post-catalyst O2 sensor connections are OK. O2 (signal) Pin 3 to SECM Pin B19 O2 Pin 2 (HEATER GND) to SECM (DRVG GNG) Pins A16, B17 O2 Pin 1 (HEATER PWR) to Post O2 Heater Relay. Relay pin 87. This relay only turns on after engine has been running for some time and SECM has calculated that water condensation in exhaust has been removed by exhaust heat. Post O2 Heater Relay has SECM (DRVP + 12V) applied to the relay coil power. The relay coil ground is controlled by SECM Pin A20 to activate the relay to flow current through the post O2 heater. Verify O2 sensor heater circuit is operating by measuring heater resistance (2.1 Ω ± 0.4 Ω) O2 Pin 2 (HEATER GND) to Pin 1 (HEATER PWR)
743	Reserved		
751	**GasO2FailedLean** Pre-catalyst O2 sensor indicates extended lean operation on LPG	(1) TurnOnMil (2) DisableGas O2Ctrl	Check for vacuum leaks. Check fuel trim valves, e.g. leaking valve or hose. Check for missing orifice(s).
752	**GasPostO2FailedLean** Pre-catalyst O2 sensor indicates extended lean operation on LPG	(1) TurnOnMil (2) DisableGasPost O2Ctrl	Correct other faults that may contribute to 752 (e.g. faults pertaining to dither valves, Pre-Cat O2, Post Cat O2 sensor) Check for vacuum leaks Check for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 742 corrective actions).

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
771 (77)	**GasO2FailedRich** Pre-catalyst O2 sensor indicates extended rich operation on LPG	(1) TurnOnMil (2) DisableGas O2Ctrl	Check fuel trim valves, e.g. plugged valve or hose. Check for plugged orifice(s).
772	**GasPostO2FailedRich** Pre-catalyst O2 sensor indicates extended rich operation on LPG	(1) TurnOnMil (2) DisableGasPostO2Ctrl	Correct other faults that may contribute to 772 (e.g. faults pertaining to FTVs, Pre-Cat O2, Post Cat O2 sensor) Look for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 742 corrective actions).
821	**LiqFuelAdaptRangeHi** In Gasoline mode, system had to adapt lean more than expected	TurnOnMil	Check for vacuum leaks. Low gasoline fuel pressure, perform gasoline pressure test. Injector problems, e.g. plugged, defective injector.
831	**LiqFuelAdaptRangeLow** In Gasoline mode, system had to adapt rich more than expected	TurnOnMil	Low gasoline fuel pressure, perform gasoline pressure test Injector problems, e.g. leaking, defective injector.
841	**LiqO2NotActive** Pre-catalyst O2 sensor inactive on gasoline, open O2 sensor signal or heater leads, defective O2 sensor	(1) TurnOnMil (2) DisableLiquid O2Ctrl	Check that Pre-catalyst O2 sensor connections are OK. O2 (signal) Pin 3 to SECM Pin B13 O2 Pin 2 (HEATER GND) to SECM (DRVG GNG) Pins A16, B17 O2 Pin 1 (HEATER PWR) to SECM (DRVP + 12V) PIN A23 Verify O2 sensor heater circuit is operating by measuring heater resistance (2.1Ω ± 0.4 Ω) O2 Pin 2 (HEATER GND) to Pin 1 (HEATER PWR)

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
842	**LiqPostO2NotActive** Post-catalyst O2 sensor inactive on gasoline, open O2 sensor signal or heater leads, defective O2 sensor.	(1) TurnOnMil (2) DisableLiqPost O2Ctrl	Check that Post-catalyst O2 sensor connections are OK. O2 (return) Pin 4 to SECM Pin B1 O2 Pin 2 (HEATER GND) to SECM (DRVG GNG) Pins A16, B17 O2 Pin 1 (HEATER PWR) to Post O2 Heater Relay. Relay pin 87. This relay only turns on after engine has been running for some time and SECM has calculated that water condensation in exhaust has been removed by exhaust heat. Post O2 Heater Relay has SECM (DRVP + 12V) applied to the relay coil power. The relay coil ground is controlled by SECM Pin A20 to activate the relay to flow current through the post O2 heater. Verify O2 sensor heater circuit is operating by measuring heater resistance (2.1 Ω ± 0.4 Ω) O2 Pin 2 (HEATER GND) to Pin 1 (HEATER PWR)
843	Reserved		
851	**LiqO2FailedLean** Pre-catalyst O2 sensor indicates extended lean operation on gasoline	(1) TurnOnMil (2) DisableLiquid O2Ctrl	Check for vacuum leaks. Low gasoline fuel pressure, perform gasoline pressure test. Injector problems, e.g. plugged, defective injector
852	**LiqPostO2FailedLean** Pre-catalyst O2 sensor indicates extended lean operation on gasoline	(1) TurnOnMil (2) DisableLiqPost O2Ctrl	Correct other faults that may contribute to 852 (e.g. faults pertaining to Injectors, MAP, IAT, Pre-Cat O2, Post Cat O2 sensor. Look for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 842 corrective actions).
871	**LiqO2FailedRich** Pre-catalyst O2 sensor indicates extended rich operation on gasoline	(1) TurnOnMil (2) DisableLiquid O2Ctrl	High gasoline fuel pressure, perform gasoline pressure test Injector problems, e.g. leaking, defective injector
872	**LiqPostO2FailedRich** Pre-catalyst O2 sensor indicates extended rich operation on gasoline	(1) TurnOnMil (2) DisableLiqPostO2Ctrl	Correct other faults that may contribute to 872 (e.g. faults pertaining to Injectors, MAP, IAT, Pre-Cat O2, Post Cat O2 sensor. Look for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 842 corrective actions).

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
911	**O2RangeLow** Pre-catalyst O2 sensor voltage out of range low, sensor signal shorted to ground	(1) TurnOnMil (2) DisableLiquid O2Ctrl (3) DisableGas O2Ctrl	Check if O2 sensor installed before the catalyst is shorted to GND or sensor GND. O2 (signal) Pin 3 to SECM Pin B13 SECM (DRVG GND) Pins A16, B17 SECM (XDRG sensor GND) Pin B1
912	**O2_PostCatRangeLow** Post-catalyst O2 sensor voltage out of range low, sensor signal shorted to ground	(1) TurnOnMil (2) Disable Gasoline Post catalyst O2Ctrl (3) Disable LPG Post catalyst O2Ctrl	Check if O2 installed after the catalyst sensor is shorted to GND or sensor GND. O2 (signal) Pin 3 to SECM Pin B19 Possible sources: SECM (DRVG GND) Pins A16, B17 and SECM (XDRG sensor GND) Pin B1
921	**O2RangeHigh** Pre-catalyst O2 sensor voltage out of range high, sensor signal shorted to power	(1) TurnOnMil (2) DisableLiquid O2Ctrl (3) DisableGas O2Ctrl	Check if O2 sensor installed before catalyst is shorted to +5Vdc or battery. O2 (signal) Pin 3 to SECM Pin B13 SECM (XDRP + 5V) Pin B24 SECM (DRVP + 12V) Pin A23
922	O2_PostCatRangeHigh Post-catalyst O2 sensor voltage out of range low, sensor signal shorted to ground	(1) TurnOnMil (2) Disable Gasoline Post catalyst O2Ctrl (3) Disable LPG Post catalyst O2Ctrl	Check if O2 sensor installed after catalyst is shorted to +5Vdc or battery. O2 (signal) Pin 3 to SECM Pin B19 Possible voltage sources: SECM (XDRP + 5V) Pin B24 and SECM (DRVP + 12V) Pin A23
931	**FuelTempRangeLow** Fuel Temperature Sensor Input is Low normally set if the fuel temperature sensor wire has shorted to chassis ground or the sensor has failed.	TurnOnMil	Check fuel temp sensor connector and wiring for a short to GND SECM (signal) Pin B14 to FTS Pin 1 SECM (sensor GND) Pin B1 to FTS Pin 2 SECM (system GND) Pin A16, B17
932	**FuelTempRangeHigh** Fuel Temperature Sensor Input is High normally set if the fuel temperature sensor wire has been disconnected or the circuit has opened to the SECM.	TurnOnMil	Check if fuel temp sensor connector is disconnected or for an open FTS circuit SECM (signal) Pin B14 to FTS Pin 1 SECM (sensor GND) Pin B1 to FTS Pin 2

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
933	**TransOilTemp** Excessive transmission oil temperature	(1) TurnOnMil (2) Delayed EngineShutdown	Refer to drivetrain manufacturer's transmission service procedures
991	**ServiceFault1** Service Interval 1 has been reached	None	Perform service procedure related to Service Interval 1 (determined by OEM)
992	**ServiceFault2** Service Interval 2 has been reached	None	Perform service procedure related to Service Interval 2 (determined by OEM)
993	**ServiceFault3** Service Interval 3 has been reached	None	Perform service procedure related to Service Interval 3 (determined by OEM)
994	**ServiceFault4** Service Interval 4 has been reached—replace HEGO sensors	TurnOnMil	Replace Pre-catalyst HEGO sensor Replace Post-catalyst HEGO sensor
995	**ServiceFault5** Service Interval 5 has been reached—replace timing belt	TurnOnMil	Replace engine timing belt

(*) Fault actions shown are default values specified by the OEM.

Appendix

Service Tool Software (MotoView)

Introduction

The MI-07 Service Tool is a graphic interface to the SECM (Small Engine Control Module) and is made up of several screens to aid the technician in system diagnostics using a personal computer. The software application that is used to connect to the SECM is MotoView and is described in the next section. Once MotoView is connected to the SECM through the CAN cable a display file is opened (MI_07RevJ.dis) to display the available diagnostic features. The use of these features is described in Appendix.

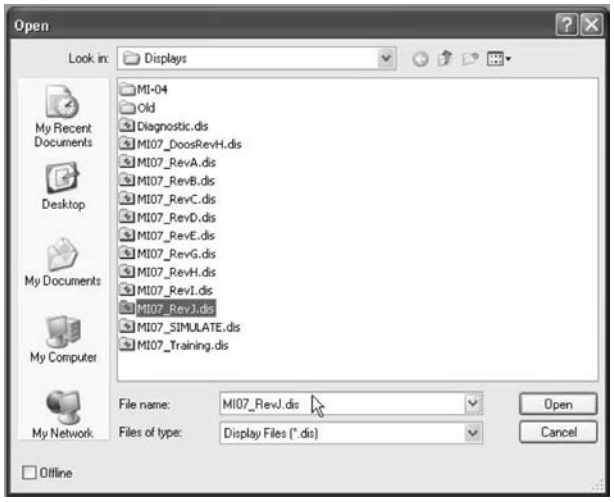


Figure 1. Opening MotoView Software

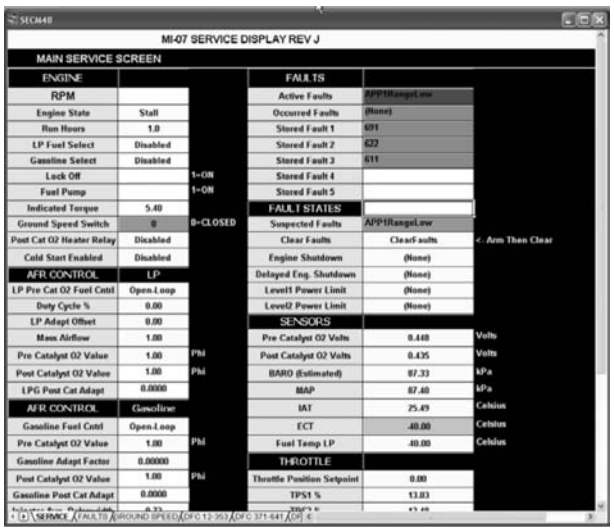


Figure 2. Display File of Available Diagnostic Features

Service Tool Software Kit

Service tool software kit consists of USB-CAN converter, Service tool software (MotoView) and Extension cable.



A408026
USB (Universal Serial Bus) to CAN (Controller Area Network) Converter Assembly



A343080
Service Tool Software (includes CD and Crypt Token (License Dongle))



A334071
Extension Cable (L=200 cm)

A334082
Extension Cable (L=20 cm)

Connection of the Service Tool

To use the Service Tool, a USB (Universal Serial Bus) to CAN (Controller Area Network) communication adapter by KVaser will be required along with a Crypt Token (Figure 3). The Crypt Token acts as a security key allowing the laptop to retrieve the necessary data from the SECM.

1. Install the Crypt Token in an available USB port in the computer (Figure 4).

2. With the ignition key in the OFF position, connect the KVaser communication cable from a second USB port on the computer to the CAN communications cable on the engine. (*If your laptop computer does not have a second USB port an appropriate USB hub will need to be used).

3. Connect a timing light to the engine.

4. Turn the ignition key to the ON position (Do Not Start the Engine).

5. Launch the MotoView program on your computer and open the Service Tool display (Figure 5).



Figure 3. KVaser Communication Adapter

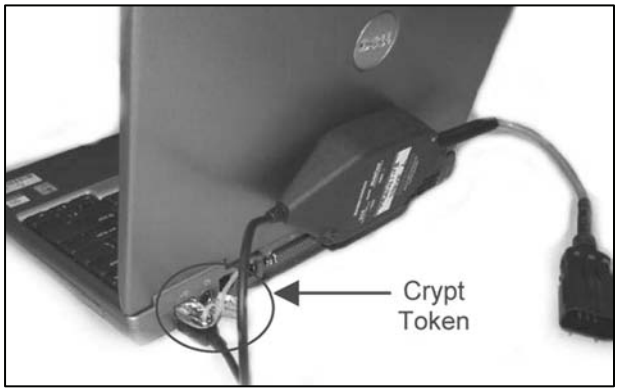


Figure 4. Crypt Token Installed on Laptop



Figure 5. Opening the Service Tool Display

MotoView Display Screens

Service Screen Tab

The first screen displayed when connecting to the SECM-48 is the Main Service Screen. The screen format is designed to give the technician a quick reference to the state of the MI-07 system and the engine. Main sections of this screen include the Engine category, Faults, Fault States, AFR Control, Sensors, Throttle, Accelerator Pedal, and Ignition.

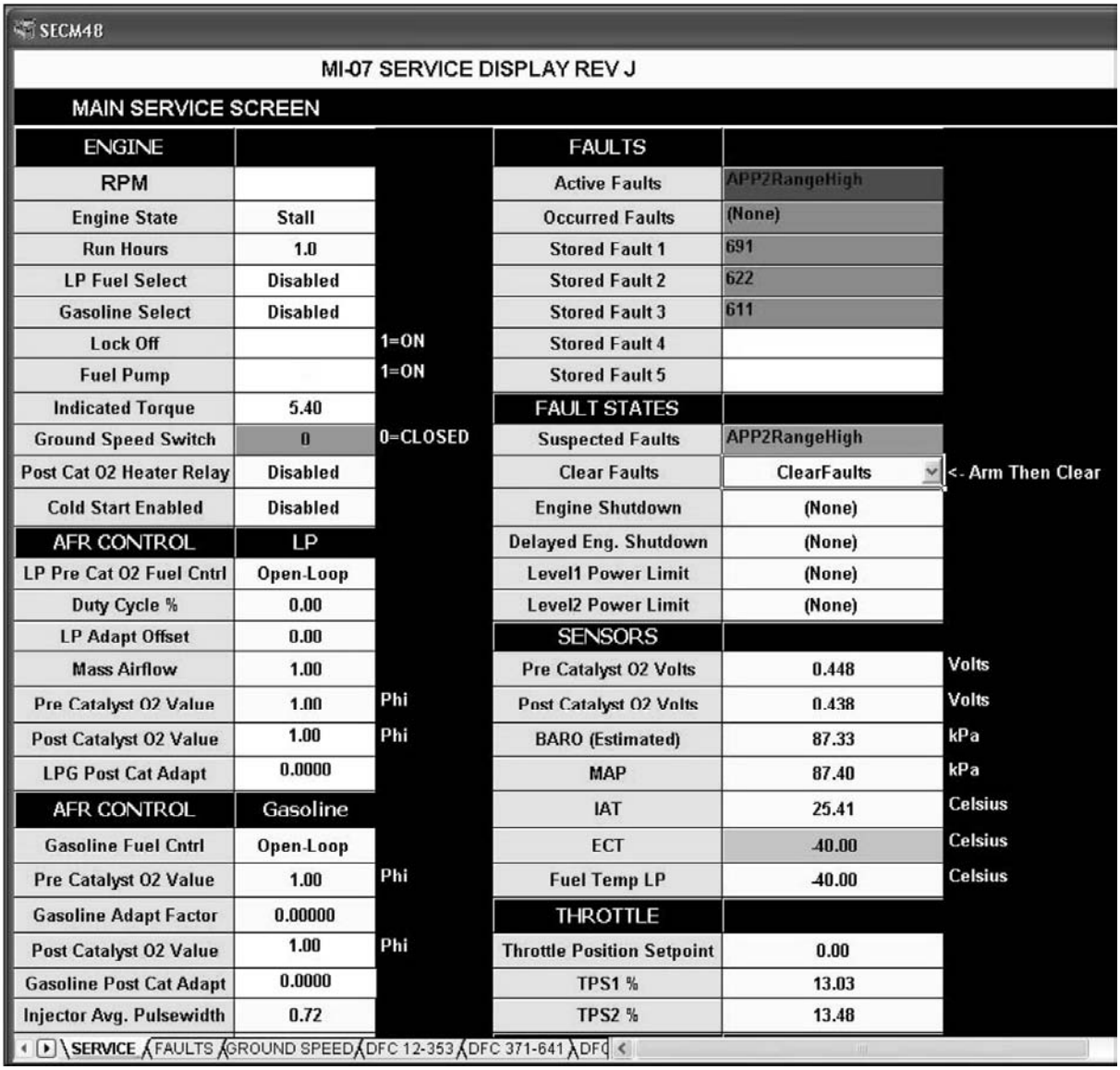


Figure 6 Main Service Screen

Engine

This category displays the engine RPM, one of three engine states (Stall, Crank, Run) and the selected fuel type. Engine run hours are also displayed in this category directly below the engine state. If the LPG fuel lock off or liquid fuel pump is active the adjacent data box will display a “1” meaning the device is on and the data box will turn green. Brief parameter notes are listed to the right of the parameter filed throughout the display screens. The indicated Torque parameter will inform you as to the amount of load placed on the engine and the Ground Speed Switch parameter displays the switch on or off, again the box will turn green if the switch is closed. The engine category also displays the status of the post O2 sensor heater replay and the cold start circuit.

AFR (Air Fuel Ratio) Control

The AFR Control category is divided into two separate sections, one for LP and a second for Gasoline, (active on bi-fuel units). Key parameters for AFR Control include the “Open-Loop”/ “Closed-Loop” control listing. This description informs the technician whether the emission system is using closed loop feedback from the oxygen sensors to control the AFR delivered to the exhaust catalyst or using tables in the engine control module for AFR control in open loop mode.

Both the pre catalyst (pre-CAT) and post catalyst (post-CAT) oxygen sensor setpoint values are displayed in Phi along with adaptive learn values. When in LP mode the FTV (Fuel Trim Valves) duty cycle is displayed in percent. If the system is running rich in closed loop, the duty cycle will increase to lean out the LP mixture to the engine. When in Gasoline operation the average fuel injector pulse width is displayed along with each individual fuel injector signal.

Faults

A brief fault list is displayed in the Fault category. Active faults display the description of all active faults—faults that are actively taking place when connected to the SECM. Occurred faults display the description of all stored faults. The first five stored faults of the ten possible fault stored record are displayed by the three digit fault codes. Definitions of these fault codes can be located on the DFC screens.

Fault States

Suspected possible faults are displayed here. (These may be redundant of the occurred fault list.) All faults can be cleared from the Clear Faults pull down parameter. Place your mouse pointer over the Clear Fault parameter box, then simply click the pull down arrow and select the Arm option. You have now armed the clear fault function. Using your mouse click the pull down arrow again and select the ClearFaults option. You must select another area on the screen by clicking that area with your mouse to complete the Clear Faults function; you will then see all faults clear. Any faults that are active will immediately be stored in the fault record. Different fault actions such as engine shutdown are also listed in this category. Any fault that causes one of these actions will be displayed next to the action itself. Only one fault at a time will be displayed next to the fault action.

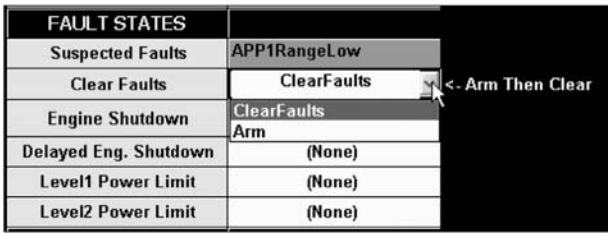


Figure 7 Clearing Faults

Sensors

Key sensor values are displayed in this category. Oxygen sensor values have been converted to voltage for easier troubleshooting using a multi-meter. ECT (Engine Coolant Temperature) will turn green when the correct engine operating temperature is reached (75°C [167°F]).

Throttle

The throttle category displays the throttle setpoint, which is the value the SECM is trying to control the throttle to. TPS (Throttle Position Sensor) 1 & 2 values are also displayed in percent.

Accelerator Pedal

APP (Accelerator Pedal Position sensor) 1&2 values are displayed in percent.

Ignition

Camshaft and crankshaft sensor synchronization is displayed along with a designator for the spark enable and the actual spark dwell.

Faults Screen Tab

The second available screen in the service tool display is the Fault screen. All ten stored fault codes are displayed in order of their occurrence. If a fault occurs and is stored it will not be stored again in the fault record until the fault has been cleared. This prevents the same re-occurring fault from being saved to all the stored records. Stored faults do not contain any type of date or time stamp to indicate when they occurred.

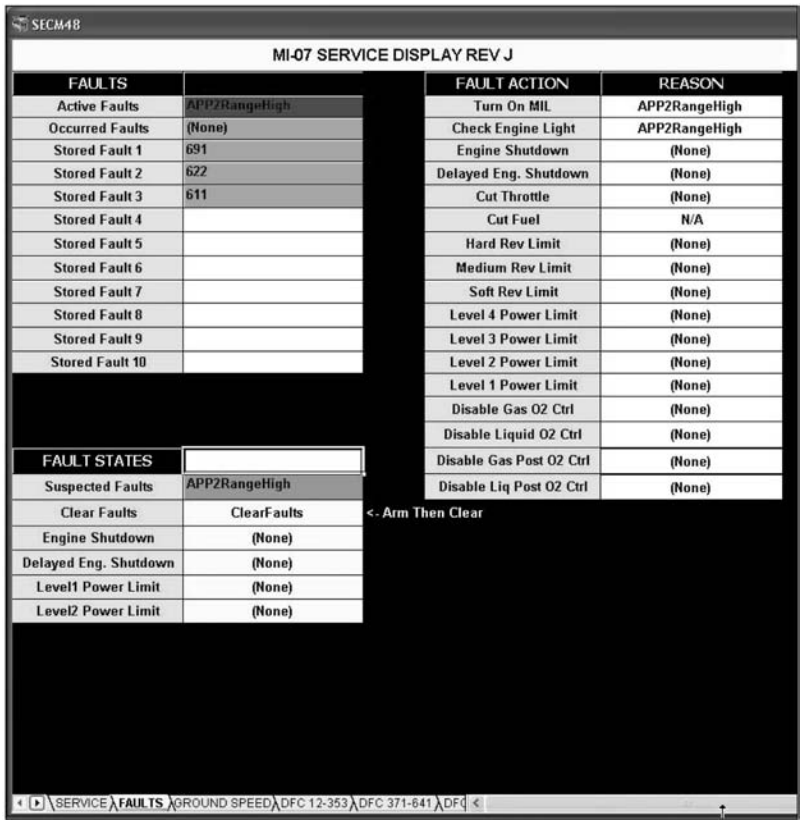


Figure 8. Faults Screen

Faults

Faults are displayed in the Fault category. Active faults display the description of all active faults, faults that are actively taking place when connected to the SECM. Occurred faults displays the description of all stored faults. The ten stored fault records are displayed by the three digit fault codes. Definitions of these fault codes can be located on the DFC screens.

Fault States

Suspected possible faults are displayed here. (These may be redundant of the occurred fault list.) All faults can be cleared from the Clear Faults pull down parameter. Place your mouse pointer over the Clear Fault parameter box, then simply click the pull down arrow and select the Arm option (Figure 7). You have now armed the clear fault function. Using your mouse click the pull down arrow again and select the ClearFaults option. You must select another area on the screen by clicking that area with your mouse to complete the Clear Faults function; you will then see all faults clear. Any faults that are active will immediately be stored in the fault record. Different fault actions such as engine shutdown are also listed in this category. Any fault that causes one of these actions will be displayed next to the action itself. Only one fault at a time will be displayed next to the fault action.

Fault Action

A list of possible fault actions is provided. Any fault that may induce one of these actions will be displayed next to the action.

Ground Speed Screen Tab

The Ground Speed screen displays parameters for the ground speed option. The Engine category of this screen gives the technician a quick reference of the engine state when making setpoint changes without having to switch screens. See the Service Screen display definitions for parameter explanations. If not used the Ground Speed Switch indicator will be open and the High Max RPM setpoint will still be active. See below for description.

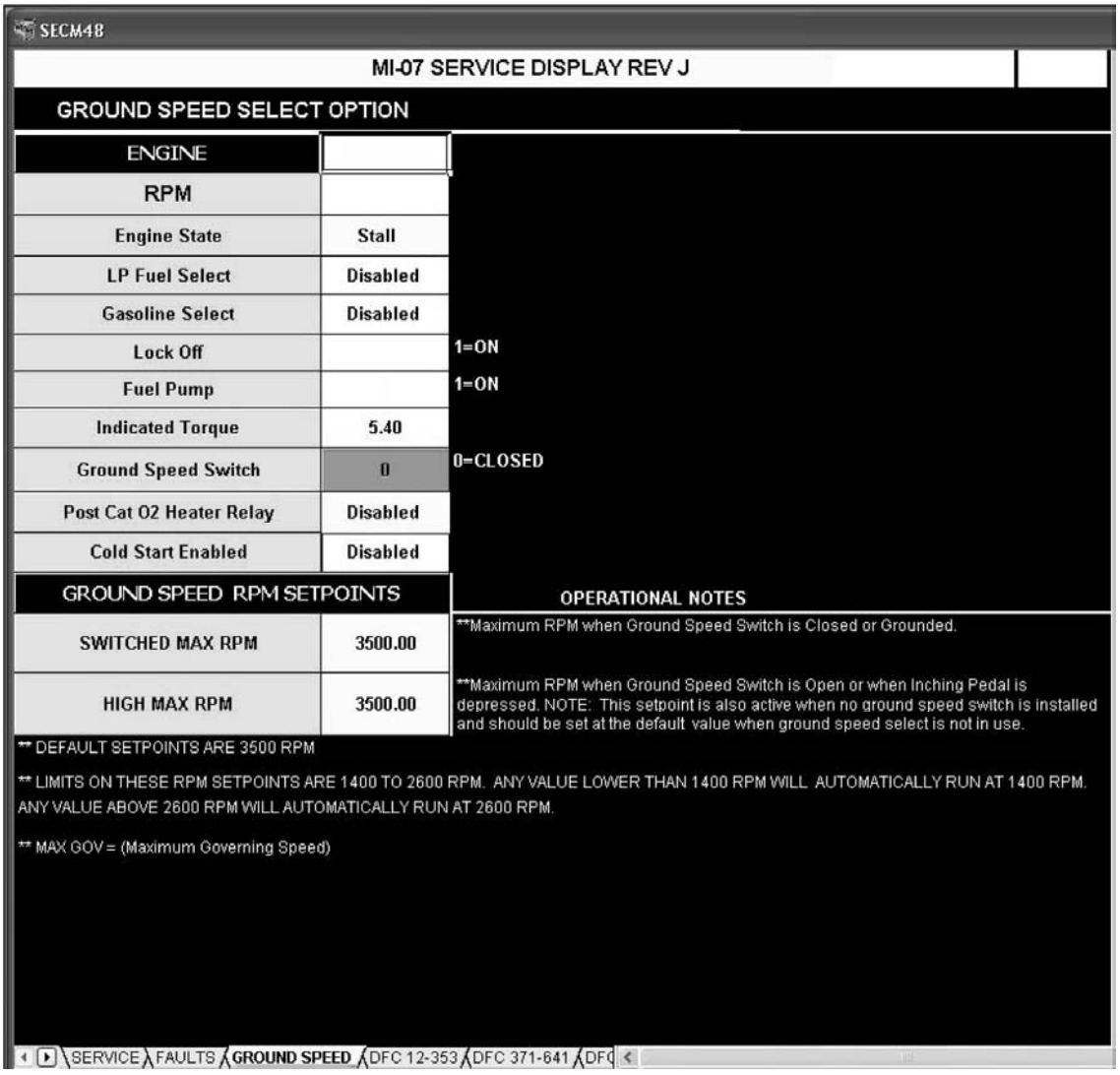
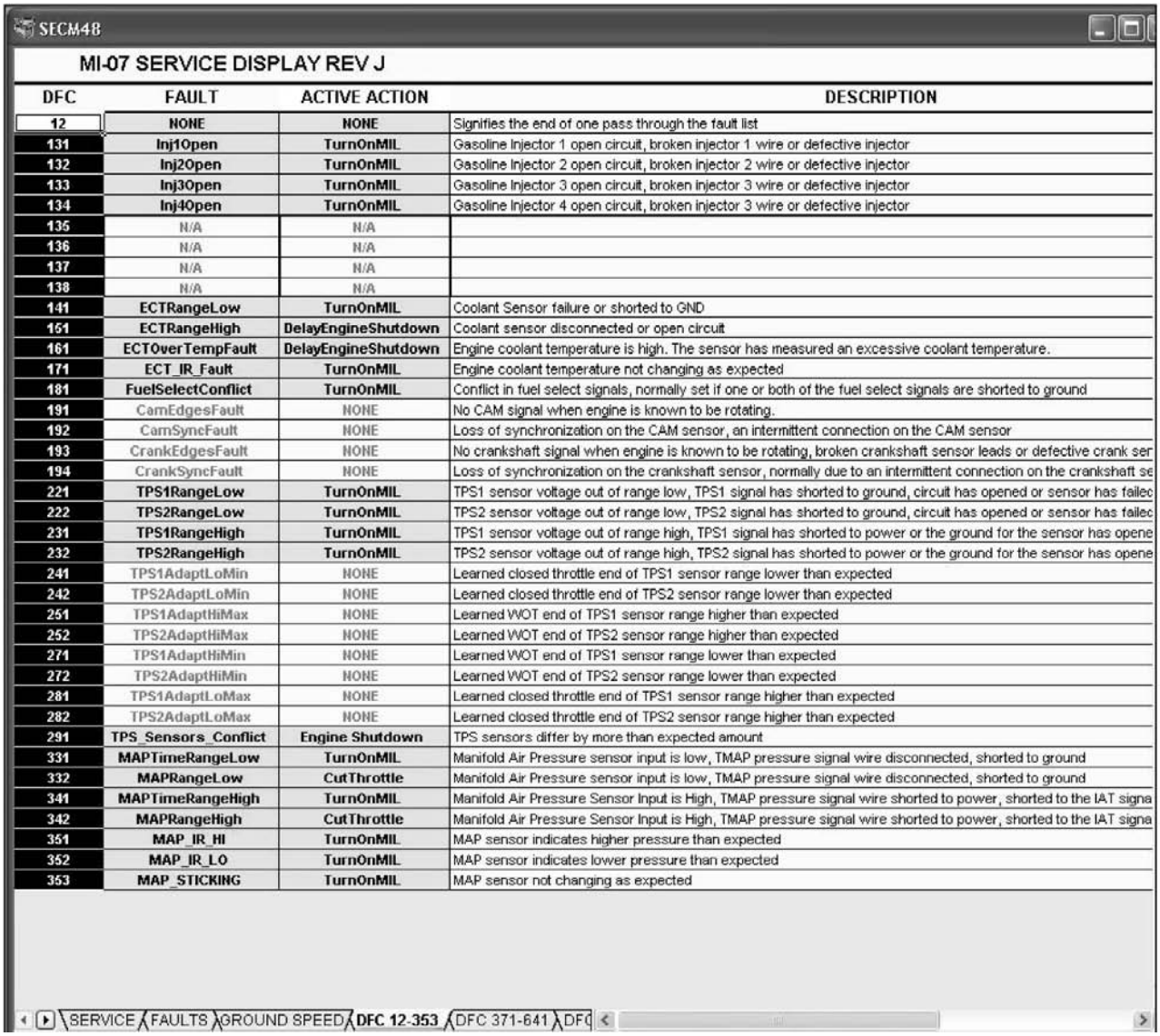

SECM48
MI-07 SERVICE DISPLAY REV J
GROUND SPEED SELECT OPTION
ENGINE
RPM
Engine State
Stall
LP Fuel Select
Disabled
Gasoline Select
Disabled
Lock Off
1=ON
Fuel Pump
1=ON
Indicated Torque
5.40
Ground Speed Switch
0
0=CLOSED
Post Cat O2 Heater Relay
Disabled
Cold Start Enabled
Disabled
GROUND SPEED RPM SETPOINTS
OPERATIONAL NOTES
SWITCHED MAX RPM
3500.00
**Maximum RPM when Ground Speed Switch is Closed or Grounded.
HIGH MAX RPM
3500.00
**Maximum RPM when Ground Speed Switch is Open or when Inching Pedal is depressed. NOTE: This setpoint is also active when no ground speed switch is installed and should be set at the default value when ground speed select is not in use.
** DEFAULT SETPOINTS ARE 3500 RPM
** LIMITS ON THESE RPM SETPOINTS ARE 1400 TO 2600 RPM. ANY VALUE LOWER THAN 1400 RPM WILL AUTOMATICALLY RUN AT 1400 RPM. ANY VALUE ABOVE 2600 RPM WILL AUTOMATICALLY RUN AT 2600 RPM.
** MAX GOV = (Maximum Governing Speed)
SERVICE
FAULTS
GROUND SPEED
DFC 12-353
DFC 371-641

Figure 9. Ground Speed Screen

Ground Speed RPM Setpoints

The ground speed RPM setpoints are active values used by the SECM. Simply highlight these values and enter a new value from your laptop computer. These values will be saved and used by the SECM even after disconnecting from the SECM and closing the display screen. If the ground switch input is closed (grounded), the Switched MAX RPM value will be used by the SECM as the maximum RPM. If the ground switch is open or not used, the High MAX RPM value will be used by the SECM as the maximum RPM. There is a limit placed on these values, the range is (1400 RPM – 2600 RPM). Any number lower than 1400 will cause the SECM to control at a maximum of 1400 RPM, any number entered above 2600 RPM will cause the SECM to control at 2600 RPM. Normal maximum governing RPM is approximately 2600RPM so the default value of 3500 RPM will not limit engine RPM in any way. The setpoint box will turn red if any value below 3500 is entered; this is simply a visual indication for the technician that a number other than the default value is being used.

DFC 12-353 Screen Tab

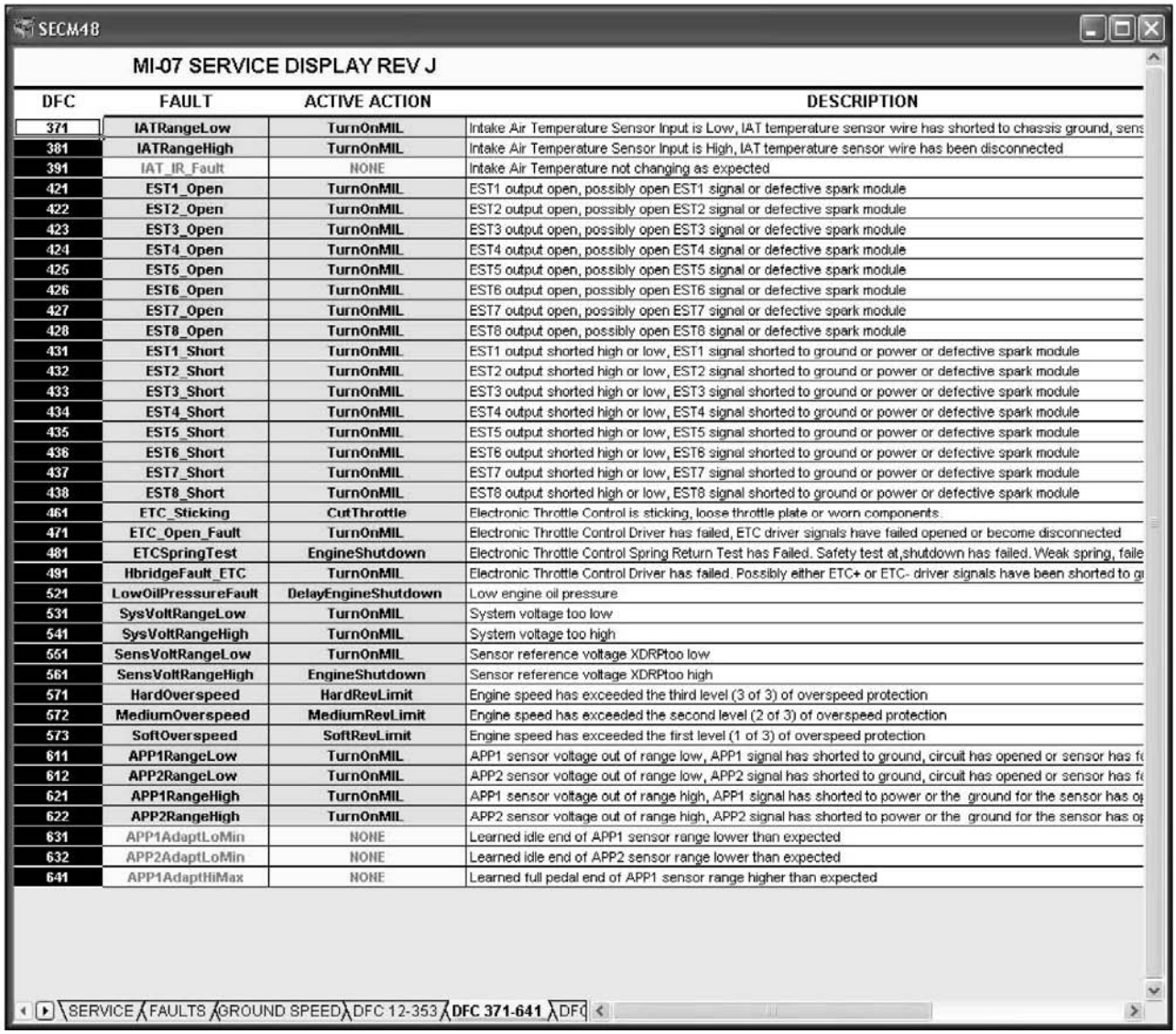


DFC	FAULT	ACTIVE ACTION	DESCRIPTION
12	NONE	NONE	Signifies the end of one pass through the fault list
131	Inj1Open	TurnOnMIL	Gasoline Injector 1 open circuit, broken injector 1 wire or defective injector
132	Inj2Open	TurnOnMIL	Gasoline Injector 2 open circuit, broken injector 2 wire or defective injector
133	Inj3Open	TurnOnMIL	Gasoline Injector 3 open circuit, broken injector 3 wire or defective injector
134	Inj4Open	TurnOnMIL	Gasoline Injector 4 open circuit, broken injector 3 wire or defective injector
135	N/A	N/A	
136	N/A	N/A	
137	N/A	N/A	
138	N/A	N/A	
141	ECTRangeLow	TurnOnMIL	Coolant Sensor failure or shorted to GND
151	ECTRangeHigh	DelayEngineShutdown	Coolant sensor disconnected or open circuit
161	ECTOverTempFault	DelayEngineShutdown	Engine coolant temperature is high. The sensor has measured an excessive coolant temperature.
171	ECT_IR_Fault	TurnOnMIL	Engine coolant temperature not changing as expected
181	FuelSelectConflict	TurnOnMIL	Conflict in fuel select signals, normally set if one or both of the fuel select signals are shorted to ground
191	CamEdgesFault	NONE	No CAM signal when engine is known to be rotating.
192	CamSyncFault	NONE	Loss of synchronization on the CAM sensor, an intermittent connection on the CAM sensor
193	CrankEdgesFault	NONE	No crankshaft signal when engine is known to be rotating, broken crankshaft sensor leads or defective crank ser
194	CrankSyncFault	NONE	Loss of synchronization on the crankshaft sensor, normally due to an intermittent connection on the crankshaft se
221	TPS1RangeLow	TurnOnMIL	TPS1 sensor voltage out of range low, TPS1 signal has shorted to ground, circuit has opened or sensor has failec
222	TPS2RangeLow	TurnOnMIL	TPS2 sensor voltage out of range low, TPS2 signal has shorted to ground, circuit has opened or sensor has failec
231	TPS1RangeHigh	TurnOnMIL	TPS1 sensor voltage out of range high, TPS1 signal has shorted to power or the ground for the sensor has opene
232	TPS2RangeHigh	TurnOnMIL	TPS2 sensor voltage out of range high, TPS2 signal has shorted to power or the ground for the sensor has opene
241	TPS1AdaptLoMin	NONE	Learned closed throttle end of TPS1 sensor range lower than expected
242	TPS2AdaptLoMin	NONE	Learned closed throttle end of TPS2 sensor range lower than expected
251	TPS1AdaptHiMax	NONE	Learned WOT end of TPS1 sensor range higher than expected
252	TPS2AdaptHiMax	NONE	Learned WOT end of TPS2 sensor range higher than expected
271	TPS1AdaptHiMin	NONE	Learned WOT end of TPS1 sensor range lower than expected
272	TPS2AdaptHiMin	NONE	Learned WOT end of TPS2 sensor range lower than expected
281	TPS1AdaptLoMax	NONE	Learned closed throttle end of TPS1 sensor range higher than expected
282	TPS2AdaptLoMax	NONE	Learned closed throttle end of TPS2 sensor range higher than expected
291	TPS_Sensors_Conflict	Engine Shutdown	TPS sensors differ by more than expected amount
331	MAPTimeRangeLow	TurnOnMIL	Manifold Air Pressure sensor input is low, TMAP pressure signal wire disconnected, shorted to ground
332	MAPRangeLow	CutThrottle	Manifold Air Pressure sensor input is low, TMAP pressure signal wire disconnected, shorted to ground
341	MAPTimeRangeHigh	TurnOnMIL	Manifold Air Pressure Sensor Input is High, TMAP pressure signal wire shorted to power, shorted to the IAT signa
342	MAPRangeHigh	CutThrottle	Manifold Air Pressure Sensor Input is High, TMAP pressure signal wire shorted to power, shorted to the IAT signa
351	MAP_IR_HI	TurnOnMIL	MAP sensor indicates higher pressure than expected
352	MAP_IR_LO	TurnOnMIL	MAP sensor indicates lower pressure than expected
353	MAP_STICKING	TurnOnMIL	MAP sensor not changing as expected

Figure 10. Diagnostic Fault Codes 12-43 Screen

DFC (Diagnostic Fault Codes) 12 through 353 are defined on this display for quick reference. Faults that are displayed in yellow have been enabled on the MI-07 system. Faults that appear in grey are included for future use but are not enabled. Refer to the service manual or the Advanced Diagnostics section of this manual for repair steps and further troubleshooting.

DFC 371-641 Screen Tab



DFC	FAULT	ACTIVE ACTION	DESCRIPTION
371	IATRangeLow	TurnOnMIL	Intake Air Temperature Sensor Input is Low, IAT temperature sensor wire has shorted to chassis ground, sens
381	IATRangeHigh	TurnOnMIL	Intake Air Temperature Sensor Input is High, IAT temperature sensor wire has been disconnected
391	IAT_IR_Fault	NONE	Intake Air Temperature not changing as expected
421	EST1_Open	TurnOnMIL	EST1 output open, possibly open EST1 signal or defective spark module
422	EST2_Open	TurnOnMIL	EST2 output open, possibly open EST2 signal or defective spark module
423	EST3_Open	TurnOnMIL	EST3 output open, possibly open EST3 signal or defective spark module
424	EST4_Open	TurnOnMIL	EST4 output open, possibly open EST4 signal or defective spark module
425	EST5_Open	TurnOnMIL	EST5 output open, possibly open EST5 signal or defective spark module
426	EST6_Open	TurnOnMIL	EST6 output open, possibly open EST6 signal or defective spark module
427	EST7_Open	TurnOnMIL	EST7 output open, possibly open EST7 signal or defective spark module
428	EST8_Open	TurnOnMIL	EST8 output open, possibly open EST8 signal or defective spark module
431	EST1_Short	TurnOnMIL	EST1 output shorted high or low, EST1 signal shorted to ground or power or defective spark module
432	EST2_Short	TurnOnMIL	EST2 output shorted high or low, EST2 signal shorted to ground or power or defective spark module
433	EST3_Short	TurnOnMIL	EST3 output shorted high or low, EST3 signal shorted to ground or power or defective spark module
434	EST4_Short	TurnOnMIL	EST4 output shorted high or low, EST4 signal shorted to ground or power or defective spark module
435	EST5_Short	TurnOnMIL	EST5 output shorted high or low, EST5 signal shorted to ground or power or defective spark module
436	EST6_Short	TurnOnMIL	EST6 output shorted high or low, EST6 signal shorted to ground or power or defective spark module
437	EST7_Short	TurnOnMIL	EST7 output shorted high or low, EST7 signal shorted to ground or power or defective spark module
438	EST8_Short	TurnOnMIL	EST8 output shorted high or low, EST8 signal shorted to ground or power or defective spark module
461	ETC_Sticking	CutThrottle	Electronic Throttle Control is sticking, loose throttle plate or worn components.
471	ETC_Open_Fault	TurnOnMIL	Electronic Throttle Control Driver has failed, ETC driver signals have failed opened or become disconnected
481	ETCSpringTest	EngineShutdown	Electronic Throttle Control Spring Return Test has Failed. Safety test at,shutdown has failed. Weak spring, faile
491	HbridgeFault_ETC	TurnOnMIL	Electronic Throttle Control Driver has failed. Possibly either ETC+ or ETC- driver signals have been shorted to g
521	LowOilPressureFault	DelayEngineShutdown	Low engine oil pressure
531	SysVoltRangeLow	TurnOnMIL	System voltage too low
541	SysVoltRangeHigh	TurnOnMIL	System voltage too high
551	SensVoltRangeLow	TurnOnMIL	Sensor reference voltage XDRPtoo low
561	SensVoltRangeHigh	EngineShutdown	Sensor reference voltage XDRPtoo high
571	HardOverspeed	HardRevLimit	Engine speed has exceeded the third level (3 of 3) of overspeed protection
572	MediumOverspeed	MediumRevLimit	Engine speed has exceeded the second level (2 of 3) of overspeed protection
573	SoftOverspeed	SoftRevLimit	Engine speed has exceeded the first level (1 of 3) of overspeed protection
611	APP1RangeLow	TurnOnMIL	APP1 sensor voltage out of range low, APP1 signal has shorted to ground, circuit has opened or sensor has f
612	APP2RangeLow	TurnOnMIL	APP2 sensor voltage out of range low, APP2 signal has shorted to ground, circuit has opened or sensor has f
621	APP1RangeHigh	TurnOnMIL	APP1 sensor voltage out of range high, APP1 signal has shorted to power or the ground for the sensor has o
622	APP2RangeHigh	TurnOnMIL	APP2 sensor voltage out of range high, APP2 signal has shorted to power or the ground for the sensor has o
631	APP1AdaptLoMin	NONE	Learned idle end of APP1 sensor range lower than expected
632	APP2AdaptLoMin	NONE	Learned idle end of APP2 sensor range lower than expected
641	APP1AdaptHiMax	NONE	Learned full pedal end of APP1 sensor range higher than expected

Figure 11. Diagnostic Fault Codes 371-641 Screen

DFC (Diagnostic Fault Codes) 371 through 641 are defined on this display for quick reference. Faults that are displayed in yellow have been enabled on the MI-07 system. Faults that appear in grey are included for future use but are not enabled. Refer to the service manual or the Advanced Diagnostics section of this manual for repair steps and further troubleshooting.

DFC 642-995 Screen Tab

SECM48

MI-07 SERVICE DISPLAY REV J

	FAULT	ACTIVE ACTION	DESCRIPTION
642	APP2AdaptHiMax	NONE	Learned full pedal end of APP2 sensor range higher than expected
651	APP1AdaptHiMin	NONE	Learned full pedal end of APP1 sensor range lower than expected
652	APP2AdaptHiMin	NONE	Learned full pedal end of APP2 sensor range lower than expected
661	APP1AdaptLoMax	NONE	Learned idle end of APP1 sensor range higher than expected
662	APP2AdaptLoMax	NONE	Learned idle end of APP2 sensor range higher than expected
691	APP_Sensors_Conflict	TurnOnMIL	APP position sensors do no not track well, intermittent connections to APP or defective pedal assembly
711	LSDFault_Dither1	TurnOnMIL	Dither Valve 1 Fault, signal has opened or shorted to ground or power or defective dither 1 valve
712	LSDFault_Dither2	TurnOnMIL	Dither Valve 2 Fault, signal has opened or shorted to ground or power or defective dither 2 valve
713	LSDFault_CSValve	NONE	Cold Start Valve Fault, signal has opened or shorted to ground or power or defective cold start valve
714	LSDFault_CheckEngine	NONE	Check Engine Lamp Fault, signal has opened or shorted to ground or power or defective check engine lamp
715	LSDFault_CrankDisable	NONE	Crank Disable Fault, signal has opened or shorted to ground or power or defective crank disable relay
716	LSDFault_FuelPump	TurnOnMIL	Fuel Pump Fault, signal has opened or shorted to ground or power or defective fuel pump
717	LSDFault_LockOff	TurnOnMIL	Fuel Lockoff Valve Fault, signal has opened or shorted to ground or power or defective fuel lockoff valve
718	LSDFault_MIL	NONE	Malfunction Indicator Lamp Fault, signal has opened or shorted to ground or power or defective MIL lamp
721	GasFuelAdaptRangeLo	TurnOnMIL	In LPG mode, system had to adapt lean more than expected
731	GasFuelAdaptRangeHi	TurnOnMIL	In LPG mode, system had to adapt rich more than expected
741	GasO2NotActive	DisableGasO2Ctrl	Pre catalyst O2 sensor inactive on LPG, open O2 sensor signal or heater leads, defective O2 sensor
742	GasPostO2NotActive	DisableGasPostO2Ctrl	Post catalyst O2 sensor inactive on LPG, open O2 sensor signal or heater leads, defective O2 sensor
743	GasCatInActive	RESERVED	Post catalyst O2 sensor indicates the catalyst is inactive on LPG fuel
751	GasO2FailedLean	DisableGasO2Ctrl	Pre catalyst O2 sensor indicates extended lean operation on LPG
752	GasPostO2FailedLean	DisableGasPostO2Ctrl	Post catalyst O2 sensor indicates extended lean operation of exhaust catalyst out when operating on LPG
771	GasO2FailedRich	DisableGasO2Ctrl	Pre catalyst O2 sensor indicates extended rich operation on LPG
772	GasPostO2FailedRich	DisableGasPostO2Ctrl	Post catalyst O2 sensor indicates extended rich operation of exhaust catalyst out when operating on LPG
821	LiqFuelAdaptRangeHi	TurnOnMIL	In Gasoline mode, system had to adapt lean more than expected
831	LiqFuelAdaptRangeLow	TurnOnMIL	In Gasoline mode, system had to adapt rich more than expected
841	LiqO2NotActive	DisableLiquidO2Ctrl	O2 sensor inactive on gasoline, open O2 sensor signal or heater leads, defective O2 sensor
842	LiqPostO2NotActive	DisableLiqPostO2Ctrl	O2 sensor inactive on gasoline, open O2 sensor signal or heater leads, defective O2 sensor
843	LiqCatInActive	RESERVED	Post catalyst O2 sensor indicates the catalyst is inactive on gasoline
851	LiqO2FailedLean	DisableLiquidO2Ctrl	Pre catalyst O2 sensor indicates extended lean operation on gasoline
852	LiqPostO2FailedLean	DisableLiqPostO2Ctrl	Post catalyst O2 sensor indicates extended lean operation of exhaust catalyst out on gasoline
871	LiqO2FailedRich	DisableLiquidO2Ctrl	Pre catalyst O2 sensor indicates extended rich operation on gasoline
872	LiqPostO2FailedRich	DisableLiqPostO2Ctrl	Post catalyst O2 sensor indicates extended rich operation on gasoline
911	O2RangeLow	DisableO2Ctrl	Pre catalyst O2 sensor voltage out of range low, sensor signal shorted to ground
912	O2PostRangeLow	DisablePostO2Ctrl	Post catalyst O2 sensor voltage out of range low, sensor signal shorted to ground
921	O2RangeHigh	DisableO2Ctrl	Pre catalyst O2 sensor voltage out of range high, sensor signal shorted to power
922	O2PostRangeHigh	DisablePostO2Ctrl	Post catalyst O2 sensor voltage out of range high, sensor signal shorted to power
931	FuelTempRangeLow	TurnOnMIL	Fuel Temperature Sensor Input is Low, fuel temperature sensor wire has shorted to chassis ground or the sens
932	FuelTempRangeHigh	TurnOnMIL	Fuel Temperature Sensor Input is High, fuel temperature sensor wire has been disconnected or opened
933	TransOilTemp	TurnOnMIL	Transmission Oil Over Temperature
991	ServiceFault1	NONE	Service Interval 1 has been reached
992	ServiceFault2	NONE	Service Interval 2 has been reached
993	ServiceFault3	NONE	Service Interval 3 has been reached
994	ServiceFault4	TurnOnMIL	Service Interval 4 has been reached
995	ServiceFault5	TurnOnMIL	Service Interval 5 has been reached

DFC 642-995 | SIGNAL I/O 1 | SIGNAL I/O 2 | SIGNAL I/O 3 | SIGNAL I/O 4

Figure 12. Diagnostic Fault Codes 642-995 Screen

DFC (Diagnostic Fault Codes) 642 through 995 are defined on this display for quick reference. Faults that are displayed in yellow have been enabled on the MI-07 system. Faults that appear in grey are included for future use but are not enabled. Refer to the service manual or the Advanced Diagnostics section of this manual for repair steps and further troubleshooting.

Signal I/O Screens 1-4

There are four Signal I/O (Inputs & Outputs) screens available to assist in troubleshooting. Each screen will display SECM inputs and outputs to the various system sensors, solenoids, relays and drivers. Components are listed in categories with the signal names, values and SECM pin location. A pin out of each sensor is given along with the signal type and the corresponding SECM pin connection. System power and sensor power is actively displayed in red or orange. Ground connections are displayed in grey.

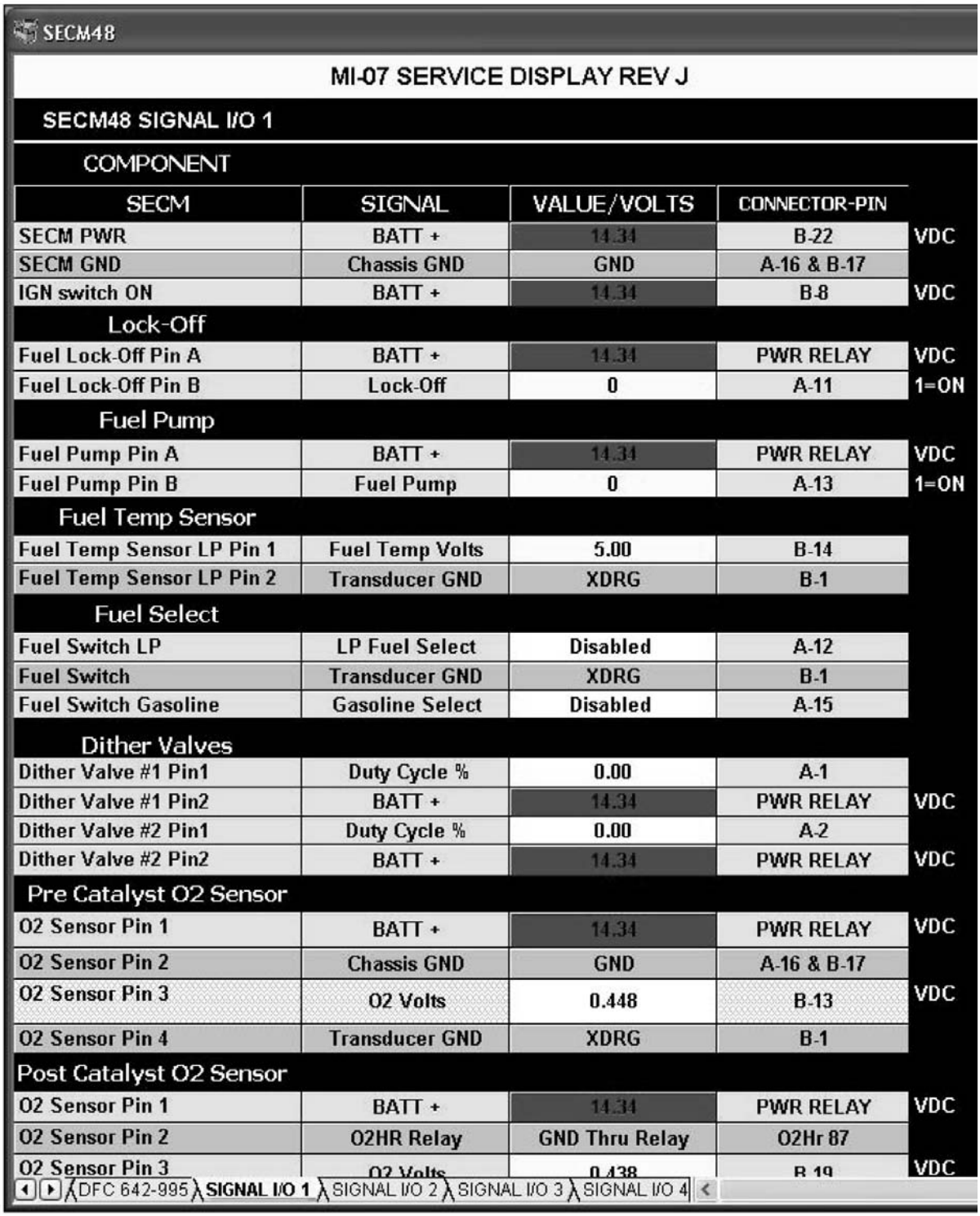

SECM48
MI-07 SERVICE DISPLAY REV J
SECM48 SIGNAL I/O 1
COMPONENT
SECM | SIGNAL | VALUE/VOLTS | CONNECTOR-PIN
SECM PWR | BATT + | 14.34 | B-22 | VDC
SECM GND | Chassis GND | GND | A-16 & B-17
IGN switch ON | BATT + | 14.34 | B-8 | VDC
Lock-Off
Fuel Lock-Off Pin A | BATT + | 14.34 | PWR RELAY | VDC
Fuel Lock-Off Pin B | Lock-Off | 0 | A-11 | 1=ON
Fuel Pump
Fuel Pump Pin A | BATT + | 14.34 | PWR RELAY | VDC
Fuel Pump Pin B | Fuel Pump | 0 | A-13 | 1=ON
Fuel Temp Sensor
Fuel Temp Sensor LP Pin 1 | Fuel Temp Volts | 5.00 | B-14
Fuel Temp Sensor LP Pin 2 | Transducer GND | XDRG | B-1
Fuel Select
Fuel Switch LP | LP Fuel Select | Disabled | A-12
Fuel Switch | Transducer GND | XDRG | B-1
Fuel Switch Gasoline | Gasoline Select | Disabled | A-15
Dither Valves
Dither Valve #1 Pin1 | Duty Cycle % | 0.00 | A-1
Dither Valve #1 Pin2 | BATT + | 14.34 | PWR RELAY | VDC
Dither Valve #2 Pin1 | Duty Cycle % | 0.00 | A-2
Dither Valve #2 Pin2 | BATT + | 14.34 | PWR RELAY | VDC
Pre Catalyst O2 Sensor
O2 Sensor Pin 1 | BATT + | 14.34 | PWR RELAY | VDC
O2 Sensor Pin 2 | Chassis GND | GND | A-16 & B-17
O2 Sensor Pin 3 | O2 Volts | 0.448 | B-13 | VDC
O2 Sensor Pin 4 | Transducer GND | XDRG | B-1
Post Catalyst O2 Sensor
O2 Sensor Pin 1 | BATT + | 14.34 | PWR RELAY | VDC
O2 Sensor Pin 2 | O2HR Relay | GND Thru Relay | O2Hr 87
O2 Sensor Pin 3 | O2 Volts | 0.438 | B-19 | VDC
DFC 642-995 | SIGNAL I/O 1 | SIGNAL I/O 2 | SIGNAL I/O 3 | SIGNAL I/O 4

Figure 13. Signal I/O Screen 1

Manual Override Screens 1 & 2

There are two manual override screens available for the technician to test for failed components or to isolate problems during troubleshooting. Manual overrides can override normal system function regardless of engine state. Active, suspected and occurred faults are displayed on each override screen for quick reference along with the ability to clear all faults.

⚠ CAUTION

Be aware of fuel flow and ignition when performing any manual override of a system component as engine damage may result.

Manual Override Screen 1

Components that can be overridden on override screen 1 include the Main Power Relay, LP fuel Lock-off, Fuel Select Switch, Electric Fuel Pump (Bi-Fuel Units), Fuel Trim Valves, O2 Sensor, and the Cold Start Valve.

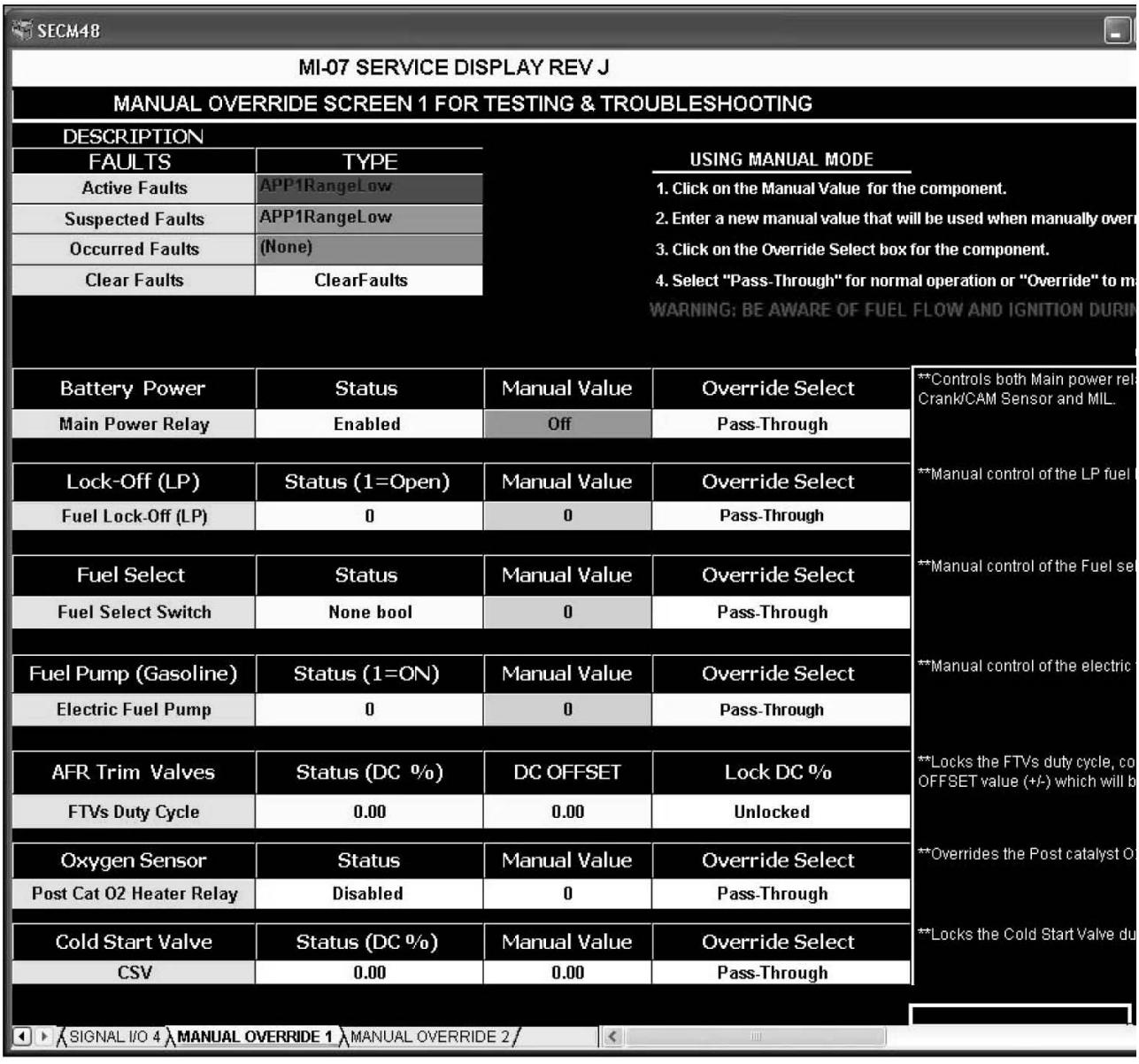


Figure 14. Manual Override Screen 1

Switched Components

To override a switched state component such as the LP lock-off, enter the desired ON/OFF (1=On, 0=Off) in the Manual Value box. Place your mouse pointer over the Override Select parameter box, then simply click the pull down arrow and select the Override option. The SECM will now be overridden and the manual value will be used to either turn on or turn off the component. The override select box will turn red when in manual override. To stop the override mode simply click the pull down arrow in the override select box and choose the "pass-through" option. Normal operation will resume. While in override you can change the manual value for ON/OFF and the component will react to the new value. Once the key switch is cycled ON then OFF, all manual overrides will return to normal operation (pass-through), regardless of the override state on the display screen.

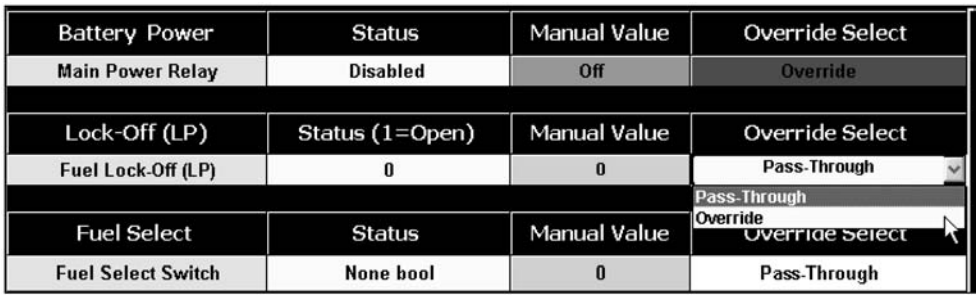


Figure 15. Overriding a Switched State Component

DC% COMPONENTS

To override a DC% (Duty Cycle%) component such as the FTVs, place your mouse pointer over the Lock DC% parameter box, then simply click the pull down arrow and select the "Locked" option. Enter the desired duty cycle in percent (0-100%) in the DC Offset box. This offset value will be added to the Status DC% value. For example: when locked the status value is 30%. If you wish to drive the component at 50% you would enter 20% in the DC Offset box (30%+20%=50%). The SECM will now be overridden and the manual value will be used to drive the component with a PWM (Pulse Width Modulated) signal. The Lock DC% box will turn red when in manual override or locked. To stop the override mode simply click the pull down arrow in the Lock DC% box and choose the "unlocked" option. Reset the DC offset to 0 % and normal operation will resume. While in override you can change the DC Offset duty cycle and the component will react to the new value. Once the key switch is cycled ON then OFF, all manual overrides will return to normal operation (pass-through) or (unlocked), regardless of the override stat on the display screen.

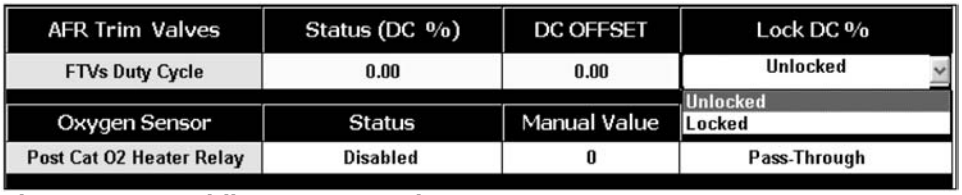


Figure 16. Overriding a Duty Cycle % Component

Components that can be overridden on override screen 2 include the Low Oil Pressure Switch, Transmission Temperature Switch, Ground Speed Switch, Spark Advance and the MIL. Four of the five selections are switched components with the exception of the manual Spark Advance.

Manual Spark Advance

To override the ignition spark advance place your mouse pointer over the Lock Spark Adv., parameter box, then simply click the pull down arrow and select the “Locked” option.

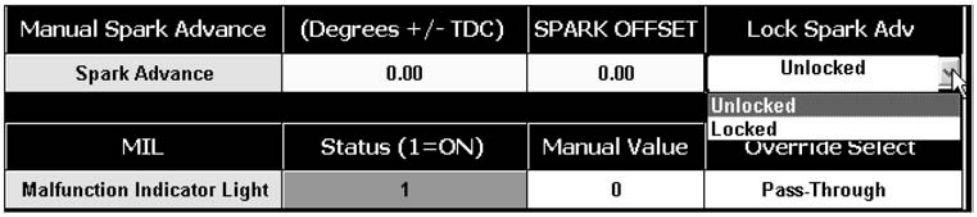


Figure 17. Overriding Ignition Spark Advance

Spark advance will be overridden and locked from the SECM. This locked spark advance value will be displayed in the (Degrees +/- TDC) box. Enter the desired spark advance in the Spark Offset box. This offset value will be added to the Spark (Degrees +/- TDC) value. For example: when locked the +/- TDC value is +8.0. If you wish to advance the spark to 10 degrees BTDC you would enter 2.0 in the Spark Offset box (8.0 + 2.0=10.0). The SECM control will now be overridden and the manual value will be used to set the spark advance through the SECM at the fixed value. The Lock Spark Adv., box will turn red when in manual override or locked. To stop the override mode simply click the pull down arrow in the Lock Spark Adv., box and choose the “unlocked” option. Reset the Spark offset to 0 and normal operation will resume. While in override you can change the Spark Offset and the ignition timing will react to the new value. Once the key switch is cycled ON then OFF, all manual overrides will return to normal operation (pass-through) or unlocked.

Manual Override Screen 2

Components that can be overridden on override screen 2 include the Low Oil Pressure Switch, Transmission Temperature Switch, Ground Speed Switch, Spark Advance, and the Malfunction Indicator Light (MIL).

⚠ CAUTION

Be aware of fuel flow and ignition when performing any manual override of a system component as engine damage may result.

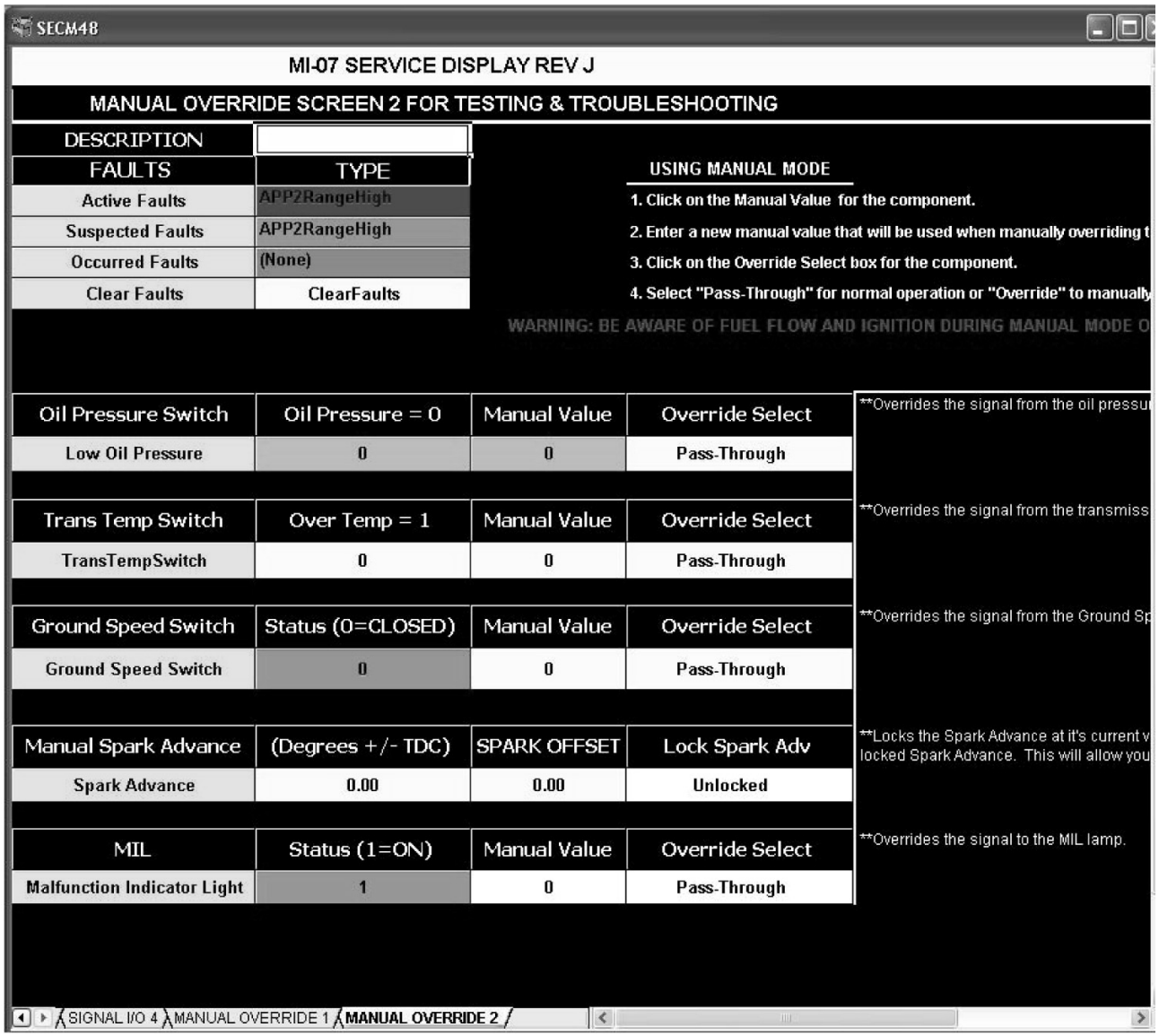


Figure 18. Manual Override Screen 2

SECM field update with Service Tool

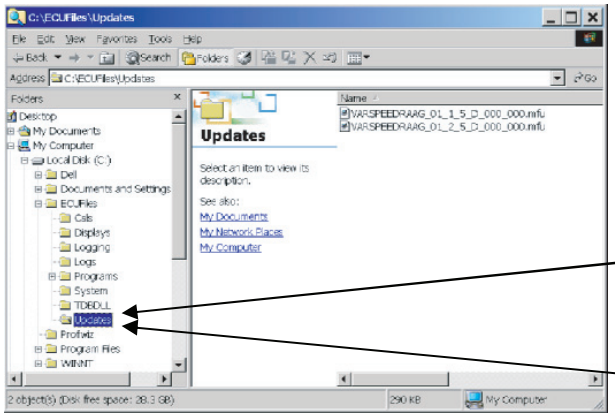
SECM controllers can be upgraded in the field using MotoUpdate software. Typically, MotoUpdate and MotoViewer applications are packaged together in the MotoService software application. Software upgrade files may be released to the field to enhance performance, provide additional features, and/or correct software problems.

This document provides step-by-step instructions for upgrading a SECM using MotoUpdate software. In order to illustrate the process, the following example upgrade is used throughout this document.

Current SECM software version:
VARSPEDDRAAF-01-2-5-D-000-000.siz (calibration ID)
Upgrade to software version:
VARSPEDDRAAG-01-2-5-D-000-000.siz (calibration ID)
Using field update file:
VARSPEDDRAAG -01-1-5-D-000.mfu
NEW Corresponding DLL file:
VARSPEDDRAAG.dll

STEP1 - LOAD UPDATE FILES INTO THE APPROPRIATE DIRECTORY

Software upgrade packages include an upgrade file (.mfu) and translation file (.dll). The (.mfu) file is required to upgrade the module, and the (.dll) is required by MotoViewer software to communicate with the module after the upgrade. Therefore, both files are provided together. Copy the field update file (.mfu) to the C:/ECUF Files/Updates directory, and the corresponding (.dll) file to C:/ECU Files/TDBDLL.

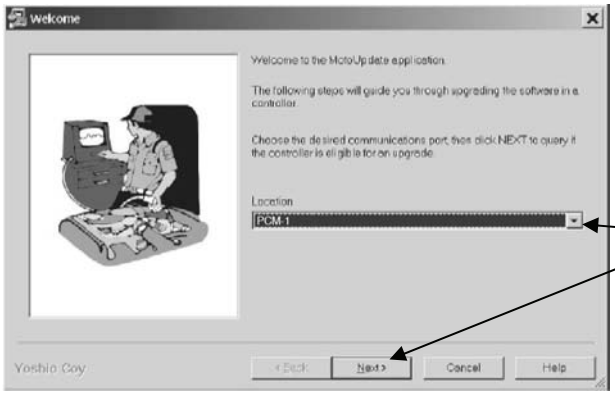


STEP 2 - CONNECT THE COMPUTER

Prior to launching the MotoUpdate software, a valid Criptoken must be installed in one of the available USB ports on the update computer. A second available USB port will be used by the USB to CAN converter. The USB to CAN coverter must then be connected to the SECM. (A USB hub must be used with computers that do not have two USB ports).

STEP 3 - LAUNCH THE MOTOUPDATE APPLICATION

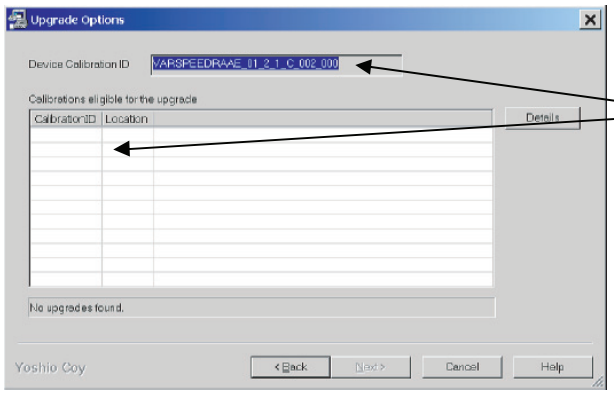
Launch the MotoUpdate application. You will see a Welcome scree.


Welcome
Welcome to the MotoUpdate application
The following steps will guide you through upgrading the software in a controller.
Choose the desired communications port, then click NEXT to query if the controller is eligible for an upgrade.
Location
PCM-1
Yoshio Coy
< Back
Next >
Cancel
Help

Select “PCM-1” in the location field, then select Next

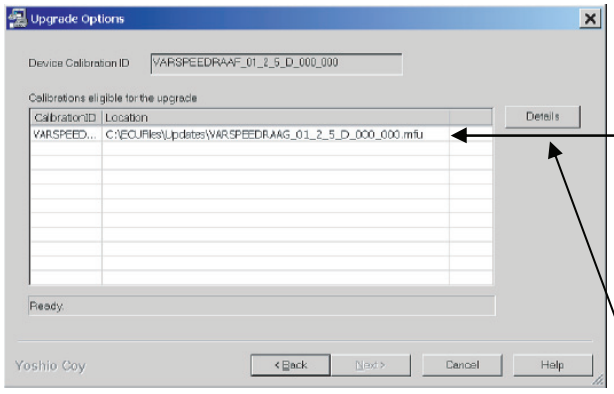
The next screen will provide a list of all of the available software upgrades available for the current engine, based upon what update files have been placed in the “Update” directory (as shown in Step-1 above). Please note that during this process, the software must query the SECM for the current software version, and therefore, the computer must be connected to the SECM and the ignition key must be in the ON position.

In general, it is usually best to see the latest revision (e.g. 001 is later than 000) in situations where multiple revisions are available. Additional information is provided in the revision matrix and/or service bulletins.



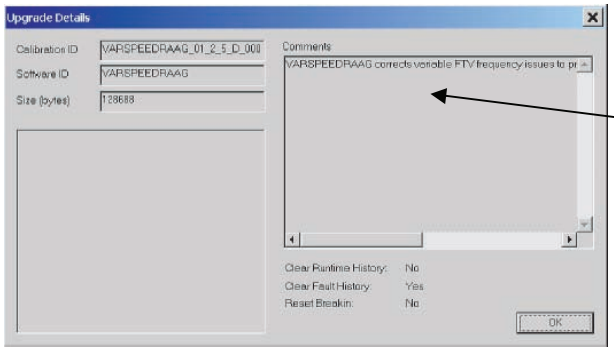
This Upgrade Options screen shows that there are no upgrades available for the listed Calibration ID. Note: If no upgrades are shown, consult the revision matrix for latest software versions.

No Upgrader Available for this Engine



This calibration ID has one (1) available upgrade

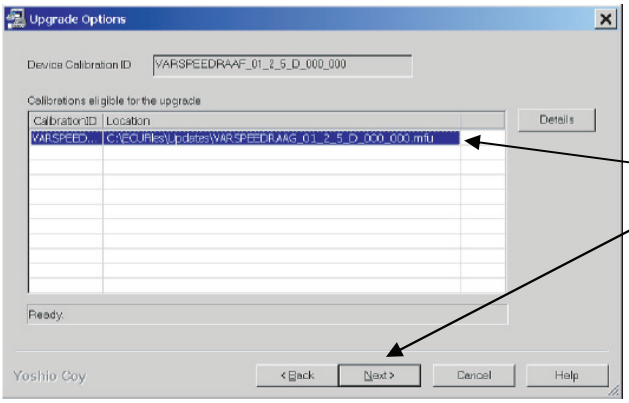
No Upgrader Available for this Engine



Selecting the “Details” button on the pervious screen will bring up the Upgrade Details screen

STEP 4 - PROGRAM THE MODULE

Once the desired upgrade is located and highlighted, select Next to upgrade ithe module.



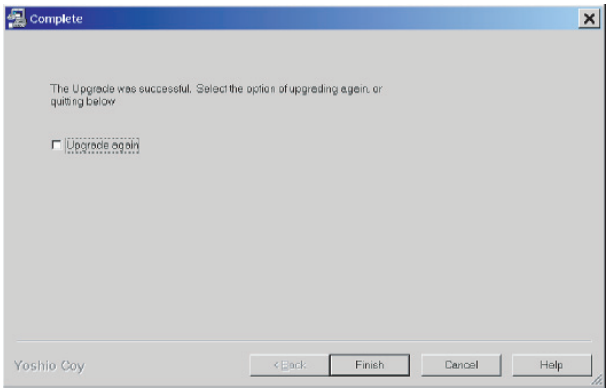
Highlight the upgrade option desired, then select Next

Follow the on-screen instructions to complete the update process. Once the programming process begins, it must run to completion. If power is interrupted or the process fails, the SECM may be rendered unusable. Several update screens will provide a running status of the upgrade process, as shown below.





Once the upgrade process is complete, a “complete” message will appear and will give the operator the option of upgrading another module. If another module is to be upgraded, select the “Upgrade again” button and select next. If another upgrade is not required, select finish.



Note 1: After successfully upgrading the SECM, MotoViewer software will not function without the appropriate translation file (.dll) discussed in Step-1 above.

Note 2: If the programming is unsuccessful, the programming process may be repeated. If repeatedly unsuccessful, please contact .

Ground Speed Limits (Option)

The maximum allowable speed of Doosan forklifts is an optional feature that can be easily activated using the MotoView service tool. This feature is very useful to customers with indoor warehouse operations.

Here's how you can activate the speed-limiting feature.

1) Install Speed control option onto the trucks

2) Set the new speed limit using the MotoView Service tool, if required.

HOW TO INSTALL SPEED LIMIT OPTION

1) Switch assy-pressure

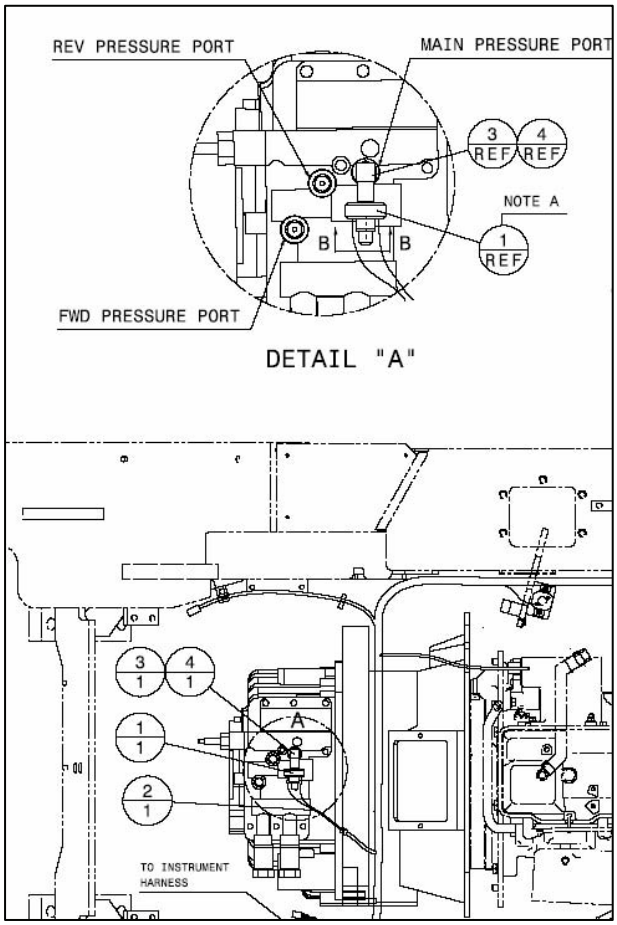
2) Jumper Harness assy

3) Elbow

4) O-ring

1. Assemble the pressure switch assy onto the main pressure port of transmission using elbow and o-ring like [Figure 1].

2. Assemble the harness assy between the pressure switch and engine wiring harness.



[Figure 1] Speed control option

How To Set New Speed Limit

Default Engine Maximum Speed

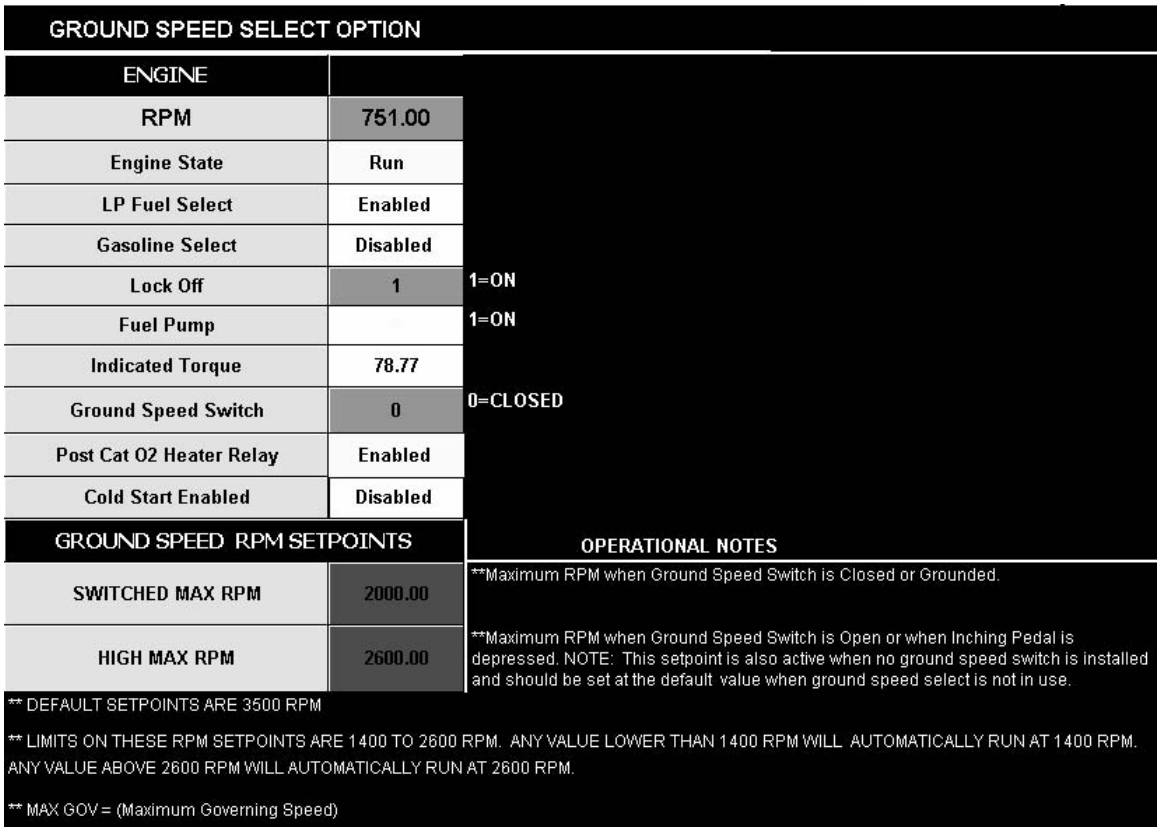
Once speed control option is assembled, the default engine maximum speed is as followed;

Forklift Model	Engine Model	Engine max. speed (rpm)	
		Neutral	In-Gear
G(C)15/18S-5 G(C)20SC-5	G420F(E)	2,450	2,000
G(C)20/25/30E-5	G420F(E)	2,600	2,000
G(C)20/25/30/33P-5 G35C-5	G424F(E)	2,600	2,000
G(C)35/40/45S-5 G(C)50/55C-5 G50/60/70S-5	G643(E)	2,500	2,000

Note :
Neutral: The inching pedal is pressed by a driver.
In-Gear: The inching pedal is NOT pressed by a driver.

How to Set New Speed Limit

Maximum RPM for both the **NEUTRAL** state (Normal) and **IN-GEAR** state (Speed Limiting) are configurable using the MotoView Service Tool.



GROUND SPEED SELECT OPTION

ENGINE		
RPM	751.00	
Engine State	Run	
LP Fuel Select	Enabled	
Gasoline Select	Disabled	
Lock Off	1	1=ON
Fuel Pump		1=ON
Indicated Torque	78.77	
Ground Speed Switch	0	0=CLOSED
Post Cat O2 Heater Relay	Enabled	
Cold Start Enabled	Disabled	

GROUND SPEED RPM SETPOINTS		OPERATIONAL NOTES
SWITCHED MAX RPM	2000.00	**Maximum RPM when Ground Speed Switch is Closed or Grounded.
HIGH MAX RPM	2600.00	**Maximum RPM when Ground Speed Switch is Open or when Inching Pedal is depressed. NOTE: This setpoint is also active when no ground speed switch is installed and should be set at the default value when ground speed select is not in use.

** DEFAULT SETPOINTS ARE 3500 RPM

** LIMITS ON THESE RPM SETPOINTS ARE 1400 TO 2600 RPM. ANY VALUE LOWER THAN 1400 RPM WILL AUTOMATICALLY RUN AT 1400 RPM. ANY VALUE ABOVE 2600 RPM WILL AUTOMATICALLY RUN AT 2600 RPM.

** MAX GOV = (Maximum Governing Speed)

[Figure 2] Ground Speed Select Screen of the MotoView Service Tool

[Figure 2] shows the Speed Limit screen of the MotoView service tool. The green boxes are configurable for both the NEUTRAL MAX RPM Setpoint and the IN-GEAR MAX RPM Setpoint. The pressure switch state is displayed at the bottom of the screen and labeled NEUTRAL SWITCH STATE.

For example, as Figure 2 depicts:

With pushing of inching pedal, the maximum RPM for normal speed governing (Neutral State) is set at 2600.

With release of inching pedal, the maximum RPM for limited speed governing (In-Gear State) is set at 2000.

Allowable Range of RPM Limits

Software limits of both Neutral and In-Gear are displayed on the right side of the Speed Limit screen. Values that are entered in the configurable “green boxes” cannot exceed the upper limit value or fall below the lower limit value.

LPG And LPG Fuel Tanks

LPG Fuel Supply

Liquefied petroleum gas (LPG) consists mainly of propane, propylene, butane, and butylenes in various mixtures. LPG is produced as a by-product of natural gas processing or it can be obtained from crude oil as part of the oil refining process. LPG, like gasoline, is a compound of hydrogen and carbon, commonly called hydrocarbons.

In its natural state, propane is colorless and odorless; an odorant (ethyl mercaptan) is added to the fuel so its presence can be detected. There are currently three grades of propane available in the United States. A propane grade designation of HD5 (not exceeding 5% propylene), is used for internal combustion engines while much higher levels of propylene (HD10) are used as commercial grade propane along with a commercial propane /butane mixture.

APPROXIMATE COMPOSITION OF HD5 PROPANE BY VOLUME

Propane (C3H8)	Propylene	Butane (C4H10)	Iso-Butane	Methane (CH4)	TOTAL
90.0% min.	5% max.	2.0%	1.5%	1.5%	100%

An advantage of LPG is the ability to safely store and transport the product in the liquid state. In the liquid state propane is approximately 270 times as dense as it is in a gaseous form. By pressurizing a container of LPG we can effectively raise the boiling point above –44 deg. C / -42 deg. C, keeping the propane in liquid form. The point at which the liquid becomes a gas (boiling point) depends on the amount of pressure applied to the container.

This process operates similarly to an engine coolant system where water is kept from boiling by pressurizing the system and adding a mixture of glycol. For example water at normal atmospheric pressure will boil at 212 deg. F / 100 deg. C. If an engines operating temperature is approximately 230 deg. F / 110 deg. C, then the water in an open un-pressurized cooling system would simply boil off into steam, eventually leaving the cooling system empty and over heating the engine. If we install a 10 PSIG cap on the radiator, pressurizing the cooling system to 10 PSIG, the boiling point of the water increases to 242 deg. F / 117 deg. C, which will cause the water to remain in liquid state at the engines operating temperature.

The same principle is applied to LPG in a container, commonly referred to as an LPG tank or cylinder. Typically an LPG tank is not filled over 80% capacity allowing for a 20% vapor expansion space. Outside air temperature effect's an LPG tank and must be considered when using an LPG system. (Figure 2) shows the relationship between pressure and temperature in a LPG tank at a steady state condition.

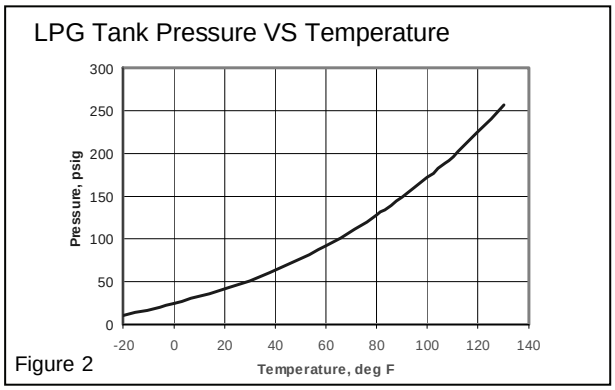


Figure 2

With 128 PSIG vapor pressure acting against the liquid propane the boiling point has been raised to slightly more than 80 deg. F / 27 deg. C.

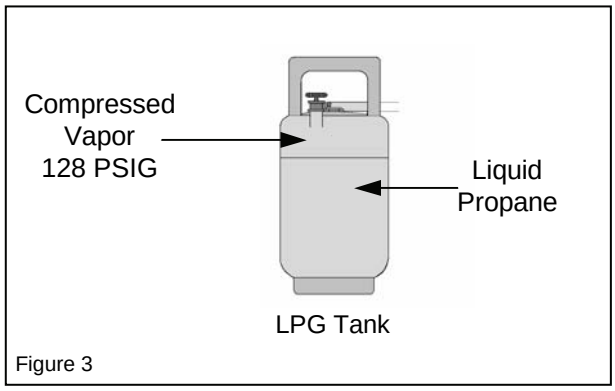


Figure 3

NOTE: Vapor pressure inside an LPG tank depends on the ambient air temperature outside the tank, not the amount of liquid inside the tank. A tank that is ¾ full of liquid propane at 80 deg. F will contain the same vapor pressure as a tank that is only ¼ full of liquid propane.

LPG's relative ease of vaporization makes it an excellent fuel for low-rpm engines on start-and-stop operations. The more readily a fuel vaporizes the more complete combustion will be.
Because propane has a low boiling point (-44F), and is a low carbon fuel, engine life can be extended due to less cylinder wall wash down and little, if any, carbon build up.

LPG Fuel Tanks

The two styles of LPG storage containers available for industrial use and lift truck applications are portable universal cylinders and permanently mounted tanks. Portable universal cylinders are used primarily for off-highway vehicles and are constructed in accordance with the DOT-TC (United States Department of Transport – Transport Canada). The cylinders are referred to as universal because they can be mounted in either a vertical or horizontal position (Figure 4).



Figure 4

NOTE: A 375-psig, relief valve is used on a DOT forklift tank. The relief valve must be replaced with a new valve after the first 12 years and every 10 years thereafter.

The tank must be discarded if the collar is damaged to the point that it can no longer protect the valves. It must also be replaced if the foot ring is bent to the point where the tank will not stand or is easily knocked over.

Installing LPG Fuel Tanks

When installing a tank on a lift truck, the tank must be within the outline of the vehicle to prevent damage to the valves when maneuvering in tight spaces. Horizontal tanks must be installed on the saddle that contains an alignment pin, which matches the hole in the collar of the tank. When the pin is in the hole, the liquid withdrawal tube is positioned to the bottom of the tank. A common problem is that often these guide-pins are broken off, allowing the tank to be mounted in any position. This creates two problems. 1). When the liquid withdrawal tube is exposed to the vapor space, it may give a false indication that the tank is empty, when it actually is not. 2). The safety relief valve may be immersed in liquid fuel. If for any reason the valve has to vent, venting liquid can cause a serious safety problem,

⚠ CAUTION

When empty, the tank is exchanged with a pre-filled replacement tank. When exchanging a tank, safety glasses and gloves should be worn.

LPG Fuel Tank Components

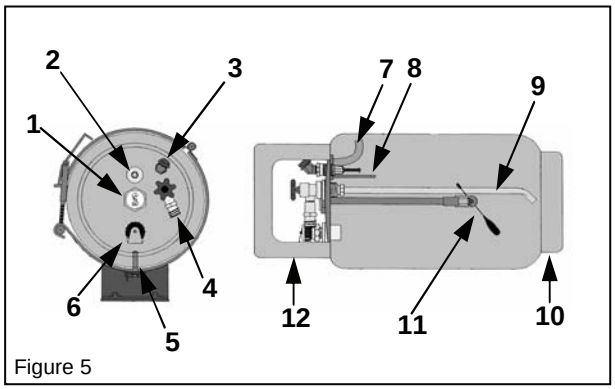


Figure 5

(1) Fuel Gauge (2) 80% Stop Bleeder
(3) Pressure Relief Valve
(4) Service Valve (Tank end male coupling) (5) Filler Valve
(6) Alignment Pin
(7) Vapor Withdrawal Tube (Only used with Vapor Withdrawal)
(8) 80% Limiter Tube (9) Liquid Withdrawal Tube
(10) Foot Ring (11) Fuel Level Float (12) Collar

Fuel Gauge

In figure 5 a visual fuel gauge is used to show the fuel level in the tank. A mechanical float mechanism detects the liquid propane level. A magnet on the end of the float shaft moves a magnetic pointer in the fuel gauge. Some units have an electronic sending unit using a variable resistor, installed in place of a gauge for remote monitoring of the fuel level. The gauge may be changed with fuel in the tank. **DO NOT REMOVE THE FOUR LARGE FLANGE BOLTS THAT RETAIN THE FLOAT ASSEMBLY, WITH FUEL IN THE TANK!**

⚠ CAUTION

It is not a legal practice to fill the tank through the liquid contents gauge.

In some applications a fixed tube fuel indicator is used in place of a float mechanism. A fixed tube indicator does not use a gauge and only indicates when the LPG tank is 80% full. The fixed tube indicator is simply a normally closed valve that is opened during refueling by the fueling attendant. When opened during refueling and the tanks LPG level is below 80%, a small amount of vapor will exit the valve. When the LPG tank level reaches 80% liquid propane will begin exiting the valve in the form of a white mist (Always wear the appropriate protective apparel when refueling LPG cylinders). In order for this type of gauge to be accurate, the tank must be positioned properly. When full (80% LPG) the valve is closed by turning the knurled knob clockwise. Typically a warning label surrounds the fixed tube gauge which reads **STOP FILLING WHEN LIQUID APPEARS.**

Service Valve

The service valve is a manually operated valve using a small hand wheel to open and close the fuel supply to the service line (fuel supply line). The service valve installs directly into the tank and has two main categories, liquid and vapor service valves. Liquid service valves used on portable LPG tanks use a 3/8" (3/8" NPT) male pipe thread on the service valve outlet for attachment of a quick disconnect coupler.

An excess flow valve is built into the inlet side of the service valve as a safety device in case of an accidental opening of the service line or damage to the service valve itself. The excess flow valve shuts off the flow of liquid propane if the flow rate of the liquid propane exceeds the maximum flow rate specified by the manufacturer.

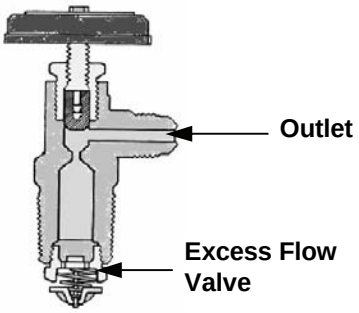


Figure 6

⚠ CAUTION

When the tank is in use the service valve should be completely open. If the valve is partly open, the vehicle may not be getting enough fuel to operate efficiently.

In addition to possibly starving the engine for fuel, a partly open valve may restrict the flow enough to prevent the excess flow valve from closing in the event of a ruptured fuel line.

Most liquid service valves have an internal hydrostatic relief valve and are usually labeled **"LIQUID WITH INTERNAL RELIEF"**. The hydrostatic relief valve protects the fuel service line between the tank and the lock off from over pressurization. The internal hydrostatic relief valve has a minimum opening pressure of 375 PSIG and a maximum pressure of 500 PSIG. These type of relief valves have an advantage over external relief valves because the propane is returned to the tank in the event of an over pressurization instead of venting the propane to atmosphere.

Quick Disconnect Coupling

The liquid withdrawal or service valve on a DOT tank has male threads and accepts the female portion of a quick disconnect coupling (Figure 8). The female portion is adapted to the liquid hose going to the fuel system. Both halves are equipped with 100% shutoffs, which open when coupled together to allow fuel flow. The coupler has two seals. One is an o-ring and the other is a flat washer. The o-ring prevents leakage from the shaft on the other coupling and the flat washer seals when the coupler is fully connected.

NOTE: The flat seal and / or the o-ring will sometimes pop off when disconnecting and slide up the shaft of the mating connector, causing the valve not to open when fully mated. The extra washer or o-ring must be removed from the shaft and the coupling reconnected.

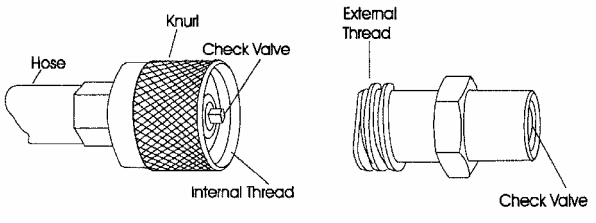


Figure 8

Filler Valve

The liquid filler valve (Figure 9) has a male thread to receive a fuel nozzle and typically has a plastic or brass screw on cap that is retained with a small chain or plastic band to keep debris out of the filler valve. The filler valve is a one-way flow device that uses two check valves to allow fuel to enter the tank but prevent it from exiting. Both check valves are backpressure type check valves, designed so that backpressure from the tank assists the check valves own spring pressure to close the valve. The first valve uses a neoprene on metal seal and the second valve uses a metal on metal seal.

A weakness ring is machined into the filler valve just above the check valves and will allow the filler valve to shear off in case of an accident. The valve will break or shear off above the check valves so that the tank will be sealed and no liquid propane can escape.

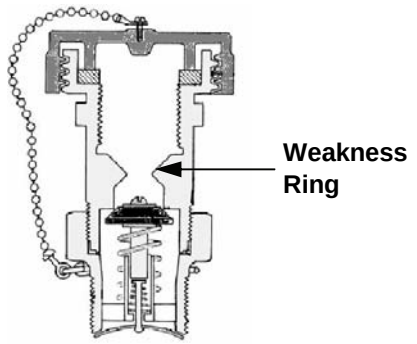


Figure 9

Regulatory Compliance

EPA / CARB Emissions Certification

When properly applied and calibrated, 's MI-07 control system is capable of meeting EPA 2007 LSI emission standards (40 CFR Part 1048.101) when operating properly with an approved three-way catalyst. The emission standards, including appropriate deterioration factors over the useful life of the system, are as follows:

HC+NOx: 2.0 g/hp-hr [2.7 g/kW-hr]
CO: 3.3 g/hp-hr [4.4 g/kW-hr]

Evaporative emissions comply with 40 CFR Part 1048.105. These standards apply only to volatile liquid fuels such as gasoline. Note that the engine crankcase must be closed.

North American Compliance

The N-2007 regulator is UL listed per Category ITPV LP-Gas Accessories, Automotive Type.

The N-2007 regulator and CA100 mixer have tamper-resistant features approved by CARB.

Special Conditions for Safe Use

Field wiring must be suitable for at least 248°F (120°C).

SECM-48 inputs are classified as permanently connected IEC measurement Category I. To avoid the danger of electric shock, do not use inputs to make measurements within measurement categories II, III, or IV.

SECM-48 input power must be supplied from a power supply/battery charger certified to IEC standard with a SELV (Safety Extra Low Voltage) classified output.

SECM-48 inputs and outputs may only be connected to other circuits certified as SELV (Safety Extra Low Voltage).

⚠ WARNING—EXPLOSION HAZARD

Do not connect or disconnect while circuit is live unless area is known to be non-hazardous.

Substitution of components may impair suitability for Class I, Division 2, or Zone 2 applications.

Electrostatic Discharge Awareness

All electronic equipment is static-sensitive, some components more than others. To protect these components from static damage, you must take special precautions to minimize or eliminate electrostatic discharges.

Follow these precautions when working with or near the control.

1. Before doing maintenance on the electronic control, discharge the static electricity on your body to ground by touching and holding a grounded metal object (pipes, cabinets, equipment, etc.).

2. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.

3. Keep plastic, vinyl, and Styrofoam materials (such as plastic or Styrofoam cups, cup holders, cigarette packages, cellophane wrappers, vinyl books or folders, plastic bottles, and plastic ash trays) away from the control, the modules, and the work area as much as possible.

Abbreviations

ACFM	Actual cubic feet per minute at the specified suction conditions
AFR	Air fuel ratio
BHP	Brake horsepower
Bi-Fuel	Able to operate on either of two fuels
CTS	Coolant temperature sensor
CNG	Compressed natural gas
Dual Fuel	Able to run simultaneously on two fuels, e.g. diesel and natural gas. Often this term is incorrectly used to describe bi-fuel operation. Spark-ignited engines are typically bi-fuel while compression ignition engines are dual-fuel.
ECM	Engine control module
FPP	Foot pedal position
FPV	Fuel primer valve
FTS	Fuel temperature sensor
FTV	Fuel trim valve
GPM	Gallons per minute of flow
HEGO	Heated exhaust gas oxygen (sensor)
LAT	Limited-angle torque motor
LPG	Liquified petroleum gas
MAP	Manifold absolute pressure
MAT	Manifold air temperature
MIL	Malfunction indicator lamp
MOR	Manufacturer of record for emissions certification on the engine
OEM	Original equipment manufacturer
PHI	Relative fuel-air ratio or percent of stoichiometric fuel (actual fuel-air ratio / stoichiometric fuel-air ratio)
RPM	Revolutions per minute
SECM	Small engine control module
TMAP	Temperature and manifold absolute pressure
TPS	Throttle position sensor
VDC	Voltage of direct current type
VE	Volumetric efficiency
WOT	Wide open throttle